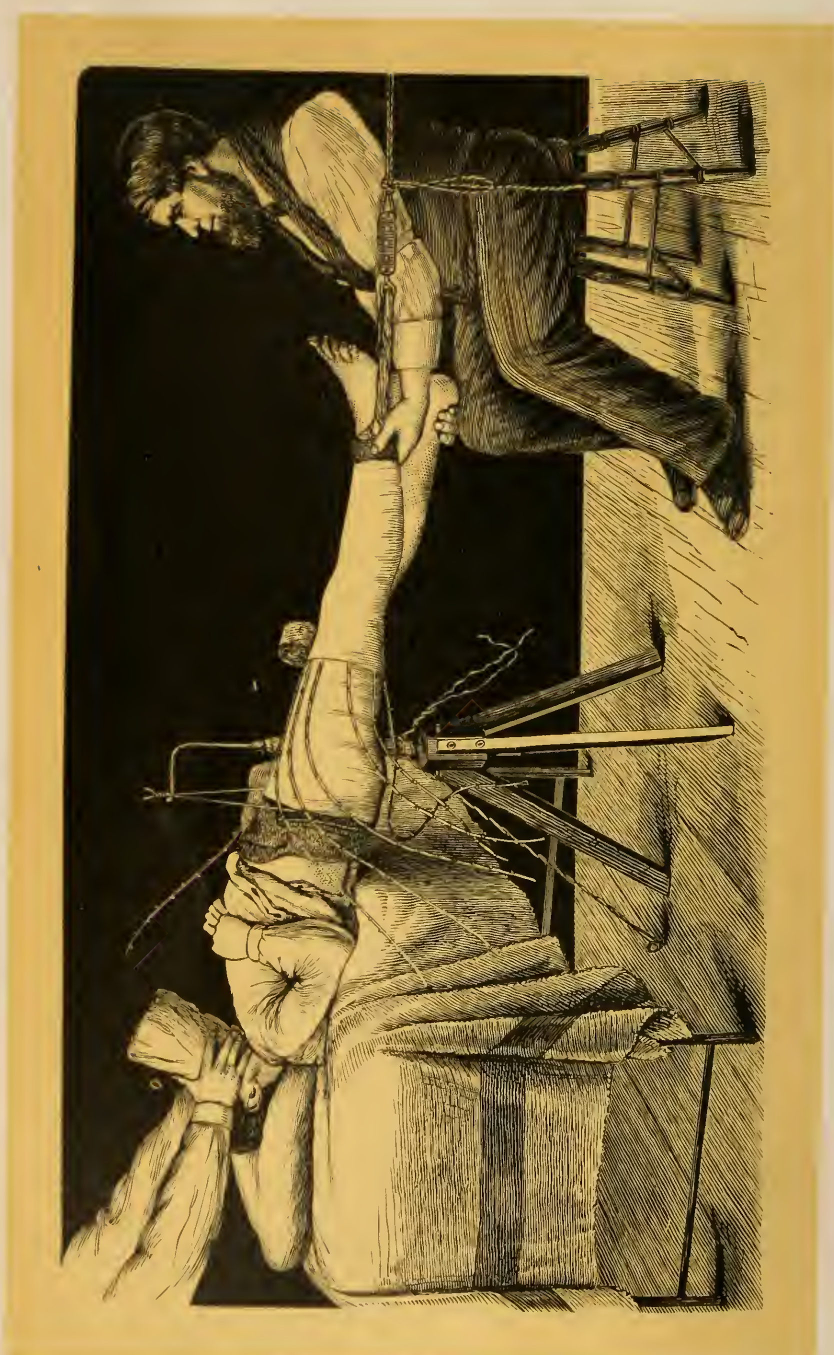
AN INQUIRY INTO THE PRINCIPLES OF TREATMENT OF BROKEN LIMBS



FRONTISPIECE

The frontispiece is from a photograph showing a subject in position upon the author's apparatus for use in applying an immovable splint to a fracture of the shaft of the femur.

The photograph was taken in 1873 before the days of officially known trained nurses and has historical value.

The seated assistant is the skilled and noted "Orderly of Ward 16."

It will be observed that the anæsthetized patient has only been moved crosswise of his bed. He has been spared the chance of serious accident in being moved from his bed to the operating-table as in the procedure shown in Plate V. The patient is so placed that there is no obstacle to his freest surgical functioning, by which is meant that his position upon the apparatus imposes no restrictions upon the use of medical or surgical measures of relief for which sudden need might arise. The capacity for extended surgical functioning may be compared with the restrictions imposed by the use of apparatus shown in Plate V. By one who, like the author, has seen sudden demands made upon the skill of the operator to meet the occurrence of serious accidents the difference in attitude of the patient for surgical functioning will be appreciated.

The author's method tends to forestall the occurrence of such accidents and affords the best conditions for their treatment should they arise. The procedure, by averting a disturbance of the injured soft parts, also tends to obviate swelling of the limb, an objectionable complication in the application of the splint.

The patient has only been shifted in position on his own bed, and may very well in case of accident be treated upon the apparatus, or, he may be easily returned in a few seconds' time to his original position in bed.

AN INQUIRY

INTO THE

PRINCIPLES OF TREATMENT

OF

BROKEN LIMBS

A PHILOSOPHICO-SURGICAL ESSAY

WITH SURGICAL NOTES

BY

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PREFACE

Soon after the author had invented the method of rapidly immobilizing broken bones by the use of perforated narrow tin strips, he explained the procedure with the aid of photographic illustrations, to a disguished physician from a distant city. His response was: "What does Professor Blank [naming an eminent surgeon] say of the merit of the method?" I then realized that it was not enough to devise an improvement of existing procedure but that it was also important to prove its value independent of the dictum of personal authority.

In the following pages I have endeavored to substitute impersonal proof of values in place of the pronouncements of personal authority or the expressions of consensus of opinion. The furthest reach of personal authority, often derived from adventitious circumstance, is to cast a presumption in favor of or against the correctness of a stated conclusion.

Some years ago in the discussion of a paper read before the Academy of Medicine on the non-operative treatment of recent simple fractures of the patella the writer was one of a small minority speaking in favor of the open method of suturing. The eminent author of the paper of the evening in closing the debate, declared he would be governed in his action by the practice of the most distinguished surgeons throughout the world and the consensus of opinion as expressed in surgical societies. In the field of empirical prac-

tice no better rule of conduct could be formulated: in scientific practice, however, in the writer's judgment, the conclusions determining the conduct of the surgeon should not be influenced by personal authority or consensus of opinion.

In his advocacy of the open method of wiring simple fractures of the patella the writer said: "The value of a method of treatment is not to be determined by reference to the fluctuating standard of professional opinion but by the comparison of the results of treatment to a single and invariable standard of perfection." (See *N. Y. Medical Record,* June 14, 1890.)

In this essay small increments of variations, even though sometimes derived from a consideration of obsolete and discarded procedures of treatment, are studied for the purpose of determining the trend of the embodied principles toward a theoretical maximum of excellence.

In laying the foundation of impersonal proof of value of methods of treatment, the author has seen fit to reduce his argument to syllogistic form.

With a common interest he has sought to proceed hand in hand with his reader in this investigation of a particular phase of truth.

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While it is conceivable that in the long processes of time there may be evolved such perfect adjustment of man to the mechanical forces to which he is exposed as to exclude the occurrence of fractures of the bones, nevertheless it may be safely assumed that this will never take place in measurable time.

No serum or other agent will ever confer immunity against these injuries, nor will measures directed to their prevention through the combating of their causation ever be completely successful. Their treatment, therefore, concerns one of the few enduring fields of surgical practice.

It may be supposed that such striking injuries as broken bones must have been the subject of thoughtful treatment from ancient times, and it is very probable that the procedures of long-continued and highly developed empiricism will often have closely approached or may sometimes have coincided with those demanded by compliance with exact theory.

In this essay the attempt is made to lift this lasting field of surgical practice from empiricism to scientific exactitude. The essay is mainly concerned in an inquiry into the principles of treatment of fractures of some of the long bones, with the object of determining the criterion of value of the results of treatment. In

this effort we are carefully to discriminate observation of the facts and their classification in defined categories, from the determination of their relative value in an ideal scheme of values. *Values attach to results,* and results may be even hypothetical without disturbance of their comparison. Indeed, the surgeon is always engaged in efforts to realize in the concrete ideal values of greater worth that have appealed to him in the abstract.

The determination of relative values is not to be confused with skill required in their practical realization. Skill is concerned merely in the practical beneficence of their realization and distribution.

Among the other advantages of a clear perception of the method of determining relative values of different methods of treatment founded upon scientific theory is the important one of conserving effort along a line of progress, with a consequent resulting tendency to uniformity of practice.

In this essay free use will be made of established common logical expressions, partly for cogency, and partly also to enable critics the more readily to expose errors into which the author may have fallen. In the use of ambiguous terms important to argument, the particular connotation of the term in the sense in which it is used, is sometimes substituted for the term itself.

The various procedures of treatment peculiar to the author's practice, some of which are avowedly obsolete, are nevertheless described for the purpose of illustration. In their presentation the author particularly considers himself relieved of any charge of

"begging the question" (*petitio principii*). The various changes from usual methods of treatment in vogue at the time, were made to meet needs for the betterment of the patient which were pressed upon his attention in each individual instance by bedside experience, and were not designed for the purpose of carrying out any preconceived theory of treatment. If any of the author's methods are adjudged of superior value, it is, so far as the argument is concerned, purely incidental.

While the author was a member of the House Staff of Bellevue Hospital in 1872, he was struck with the difficulty in many fractures of the long bones of continuously holding the fragments in a given desired adjustment pending their fixation in permanent retention apparel. To overcome this difficulty he devised a method of more speedy fixation of the fragments in adjusted relation, by means of the use of roughened narrow tin strips.

In illustration of the practicability of the method he collected into his service a large number of various recent fractures, in which the Hospital abounded and invited members of the Visiting Staff and other surgeons present at the demonstration, to select examples as tests of the method. There were chosen, a simple fracture of the shaft of the femur, a Pott's fracture with great displacement of the foot, and a fracture of both bones at the middle of the leg with great mobility at the seat of fracture. To the satisfaction of all present, these fractures were treated in turn by the method, using plaster-of-Paris band-

ages for the construction of the permanent retentive apparel.

The patient, with fracture of both bones of the leg, before treatment suffered much pain upon the slightest disturbance of his broken leg. As soon as the tin strips had been fastened in position, no anæsthetic having been given, although the plaster-of-Paris bandages were still wet, and the plaster had not begun to harden, to the surprise of the audience, the patient delightedly waved his broken leg about without pain, till he was told to desist.

Photographs of illustrative instances, together with a very brief description of the mechanical principles involved in the method, were a part of the exhibit of Bellevue Hospital sent by the Commissioners of Public Charities and Correction to the World's Fair of 1873. The author having abundant opportunity while in charge of the Reception Hospitals, which cared for a very large emergency service, as well as in other hospital services embracing a great number of fractures, amply confirmed the utility of the method. In those days, by invitation of Prof. Frank H. Hamilton, and Prof. Lewis A. Sayre, practical demonstrations of the method were given before their college classes, as well as on other occasions.

If it be conceived that in a given longitudinal plane of the leg a rigid truss extending between the fragments is fastened to the bones, obviously the fragments would be held immovable in that plane. As by reference to the diagram Fig. 1 we perceive, having to deal with soft living structures, it is possible to make rigid only the surface, or exposed mem-

ber of the truss; other members of the truss are constituted by the soft tissues themselves. The same is true of all splints as extrinsic apparel acting in resistance to forces tending to displace the adjusted fragments. However, there is a limit to the safe compression of the soft tissues by the constricting bandage and their consequent approach to rigidity, therefore it is not practicable to hold the fragments

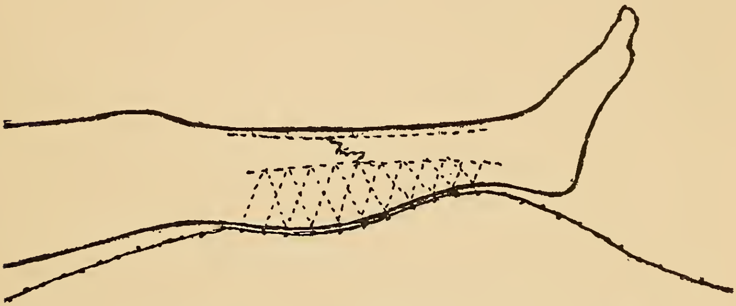

FIG. 1.—A Diagrammatic Representation of a Truss in the Median Longitudinal Plane of the Leg in a Fracture of the Tibia. Deep members of the truss are indicated by dotted lines; the superficial member of the truss is the tin strip.

of bone absolutely immobile in the presence of disturbing forces by means of any extrinsic apparel exerting its resistance through the soft parts.

An immovable plaster-of-Paris splint, encasing the limb, is efficient in resistance to displacement of the adjusted bony fragments in a degree proportional to its compression of the soft parts. Even the best applied, tightest fitting splint is incapable of holding the fragments *absolutely* immovable when they are exposed to active disturbing forces. In an instance

of a compound fracture of both bones of the leg, the author found immediately after applying a tight fitting plaster-of-Paris splint that upon introducing the finger through the wound down to the fragments, they moved upon each other when the patient gave the slightest cough, the leg lying upon the bed.

By reference to the diagram, to repeat, it will be noted that the only member of the truss that can be made rigid is the one located at the surface of the limb, the other members being constituted by the compressed living soft tissues. In the case of the plaster-of-Paris splint as usually applied, the prospective member of the truss located at the surface of the limb, at first soft and yielding, becomes rigid and effective by the hardening of the plaster-of-Paris, which requires a certain interval of time, during which the desired adjusted relation of fragments must be maintained; the longer the interval of time, the greater the probability of the disturbance of the desired relation.

In the author's invention the rigid superficial members of the truss, perfectly adapting themselves to the contour of the limb and developing rigidity when bandaged to the limb, were made of narrow tin strips and became immediately effective as a resistance to disturbing forces as soon as fastened by bandages to the surface of the limb, thus securing the advantage of limiting the required maintenance of the adjustment of the fragments in desired relation to a minimum length of time, thereby practically excluding the chances of a disturbance of that elected adjustment.

The tin strips are effective on account of the absence of extensibility and contractibility, neither lengthening nor shortening when in action as a resistance between the retaining layers of bandage. In addition to the important advantage of immobilizing the fragments of bone in the briefest interval of time, and under the most favorable conditions for their correct adjustment, they present the further advantage of scope of efficiency in affording an extended range of choice of the material that may be used for the construction of the permanent splint or apparel; the strips are even effective when secured between layers of dry bandage, but still more efficient when used between layers of wet bandage.

While the author's experience in the use of the tin strips as a means of rapidly immobilizing the bony fragments has been limited to civil practice, their superior utility in the exigencies of military practice must be evident. In military practice the promptness of setting the fracture, and consequently the quick preparation of the patient for safe transport are paramount considerations and often, no doubt, determine the question of preservation or sacrifice of the injured limb.

The time element in the treatment of fractures is so important that for "first aid," soldiers should be provided with two or three flannel bandages about three inches wide and eight yards long, two or three muslin bandages of the same dimensions and three or four antiseptic bandages of the construction originally devised by Lister. These last, apart from their antiseptic value, have a special advantage in

securing the tin strips in position. Being gummy, their folds readily stick together. In addition to the bandages, the soldier should be provided with four properly prepared tin strips.

In possession of this surgical equipment, there is the important consideration that *the broken bones may be immobilized without the use of plaster-of-Paris or even of water,* both of which may be difficult to obtain.

The flannel bandages, which at least may be sterilized, are an excellent substitute for the blanket protective covering of the limb and can be quickly applied.

The surgical material mentioned is of trivial weight. The splint being made of the strips, when fastened in position, fractures, perhaps excepting those of the thigh, could be immobilized immediately after injury, even on the battle-field. In case of fractures of the thigh, the benefit of some degree of immobilization could be obtained.

As a part of his military training every soldier should receive lessons in bandaging, which education may in an emergency be the means of saving his own or a comrade's life.

The tin strips are cut one-quarter of an inch wide from ordinary thin sheet tin. Additional length, if necessary, may be obtained by soldering two or more strips together. They are roughened that they may be securely held between layers of bandage, by punching holes along the centre line of their length. These holes are made about one inch apart, alternately on either side, by a round pointed awl. The

punching throws out little jagged points of tin around the margin of each hole, which give to the bandage an effective hold upon the strip. Care is taken not to make the holes too big, throwing out too large projecting points of tin which may interfere with the smooth application of the retaining bandage and thus obscure the outline of the limb, one of the best guides to the correct adjustment in line, of the fragments of bone. After being roughened, the strips are carefully straightened for use.

The procedure of their use in detail is as follows: taking, for an example, a fracture of both bones of the leg about the middle, with great mobility at the site of fracture. It is emphasized that the fixation of the adjusted fragments is to be accomplished by means of the tin strips, and that the material used for the construction of the permanent splint is for the continuance of the initial fixation. The use of the tin strips is not for the purpose of strengthening the constructed splint, which no doubt to some extent is a secondary effect; they are themselves the splint, within the stated connotation of the term.

The guides for the correct adjustment of the fragments at the time of their immobilization are:—the assurance of the touch, *palpation;* the *proper outline of the limb* as disclosed by its uninjured fellow; and possibly *the revelations of the fluoroscope or X-ray.* It is highly important that the adjustment of the fragments shall be accomplished under conditions wherein the guides are most helpful.

The limb is first covered with protective material to prevent immediate contact of the plaster-of-Paris

with the skin and in some slight degree to cushion tissues overlying superficial bones in places intolerant of undue pressure. In the case of the leg splint such places are the point of the heel, the instep and the tubercle and spine of the tibia. Care should be taken not to make the protective covering too thick at these designated places. No padding of cotton or other such material should ever be used. It would deform the important outline of the limb and interfere with the efficiency of the splint.

To avoid undue disturbance of the sensitive broken limb and a chance increase of swelling, it is better to adapt a covering of thin old blanket, or similar material rather than to force a stocking or other ready-made covering, upon the limb. The covering should be gently adjusted in position with such neatness and skill that it does not obscure but preserves the distinctness of the outline of the limb. The protective which covers the inner and anterior aspects of the limb should overlap that portion which covers the posterior and external surfaces. The overlying fold where the covering joins, which is held by pins with their points directed outward, should fall along the outer aspect of the limb, away from the most important outline concerned in the adjustment of the fragments, where the tibia is superficial and accessible to the touch, and thus oppose no obstacle to the scientifically made turns of the bandage. Except in fractures at the very lowermost portion of the leg it is well to have the splint include the knee-joint and infringe upon the thigh. One layer of protective covering, except in the places specified, is sufficient.

PLATE I.

Rapid Immobilization of Broken Bones of the Leg.

Upper Figure.—Limb covered with protective.

Lower Figure.—Foundation layer of plaster-of-Paris bandage; tin strips in position.

In fractures of the leg, measurements are of little value in aiding the efforts for the correction of the shortening, which is usually inconsiderable and easily sufficiently overcome, even without the use of an anæsthetic.

In bandaging *secundum artem,* which should always be practiced, the turns of the bandage should be made from the median line of the body outward across the anterior surface of the limb; in consequence, therefore, the right leg is bandaged left handedly, the left leg, right handedly, the operator standing at the patient's side with his face directed toward that of the patient. The roller bandage made of thin unbleached muslin should be rather narrow, from two to three inches wide, and six to eight yards long. A *very little* plaster-of-Paris is rubbed into each side of the bandage, just whitening it, in order that the bandage may be very easily wetted when immersed in water. Should there be much plaster upon the bandage it would be apt to form into lumps and deform the outline of the limb.

It is always to be borne in mind that the initial fixation of the adjusted fragments is to be accomplished by the action of the tin strips independently of the setting of the plaster-of-Paris, the wet bandage serving the purpose. The bandage is rolled evenly but rather loosely so it will moisten readily to the core without the plaster first setting on the outer layers. No agent should be added to the tepid water in which the bandages are immersed to hasten the setting of the plaster, indeed, a too quick setting of the plaster is to be avoided. Three or four band-

ages are immersed in the basin of tepid water. As one is used a dry one replaces it till the requisite number have been wetted. In using a bandage it should be freed from an excess of water by pressure upon it sides, avoiding pressure upon its ends. All loose ravelings should be cleared away so as not to embarrass or delay the surgeon while at work. All these details, some of them apparently trivial, are mentioned, as a regard for them contributes to the making of the perfect splint.

An assistant, comfortably seated, seizes the broken limb by the foot and drags it over the edge of the bed, giving the surgeon plenty of operating space, at the same time making moderate extension.

Commencing at the base of the toes, which are left exposed, the surgeon snugly applies one layer of bandage to the previously covered limb, as far as the designed limits of the splint. For the best construction of the splint the bandage is applied by making figure of eight turns, the reverses, where necessary, being made posteriorly, away from the more important outline of the limb. As the bandage is applied it fastens down the overlapping fold of the protective covering, permitting the removal of the retaining pins.

Practical skill in bandaging is a positive prerequisite to the construction of an immovable plaster-of-Paris splint. In preantiseptic days, when Bellevue Hospital was saturated with infection, the ever-imminent probability of the infection of a wound, especially a recent one, was a great discouragement to cutting operations. As a consequence, attention

was concentrated upon bloodless operations. In these, as well as in the septic surgery, as then practiced, bandaging played a very important part. The members of the House Staff of those days became proficient in bandaging. A novice may be taught how to make the necessary turns in bandaging, but the degree of compression of the tissues to be exerted by means of the bandage can never be adequately taught. It must be acquired by *experience.* It belongs to the *"tactus eruditus,"* an acquirement upon which the older surgeons very properly laid great emphasis. To know just what amount of compression injured tissues can safely bear, an element of their surgical functioning, is a matter of judgment gained only by *experience.* When it is considered that the greatest efficiency of the immovable apparel is developed through the greatest amount of compression that the soft tissues can safely tolerate, the careful training of the judgment and the skill necessary to insure that greatest efficiency may be appreciated.

The first layer of bandage when applied is little more than a covering of wet bandage. The splint during its construction should be kept rather wet, short of dripping. This layer of snugly and evenly applied bandage preserves the outline of the limb sharp and distinct. A little dry plaster is held in the hand under water till thoroughly moistened and then rubbed into the layer of bandage, smoothly sticking the folds together and making the proper basis for the strips to rest upon. If this basis should be judged to be not firm enough as a foundation for

the strips, which is usually the fact, a second layer of bandage is applied.

A few imaginary principal longitudinal planes of the limb are located, in which, after correcting existing deformity, immobility is to be secured.

At least four or five tin strips, as in the illustration, are used in said planes. The strips at first are to extend beyond the limits of the finished splint, from the toes to a line upon the thigh. One strip is placed on either side of the anterior median line and one in the posterior median line, respectively; the latter strip starts from beyond the toes and extends along the middle of the sole of the foot upward along the limb in the posterior median line; the former extends correspondingly along either side of the anterior median line of the limb. Two principal side strips are used, one on either side in the principal horizontal plane of the limb. They start upon the sole of the foot from beyond the toes and extend on either side of the posterior median strip to a point upon the heel where they are directed by a reverse nearly at a right angle into a general course up the limb, on either side respectively, in its principal horizontal plane.

The strips which may be prepared beforehand are secured to the foot by two or three turns of bandage and any errors in their general course along the limb are corrected at the early start. The figure of eight turns of bandage are continued, firmly securing the strips in relation to the lower fragment, as far as the place of fracture (see Plate II). During this bandaging the exposed portions of strips are uncontrolled

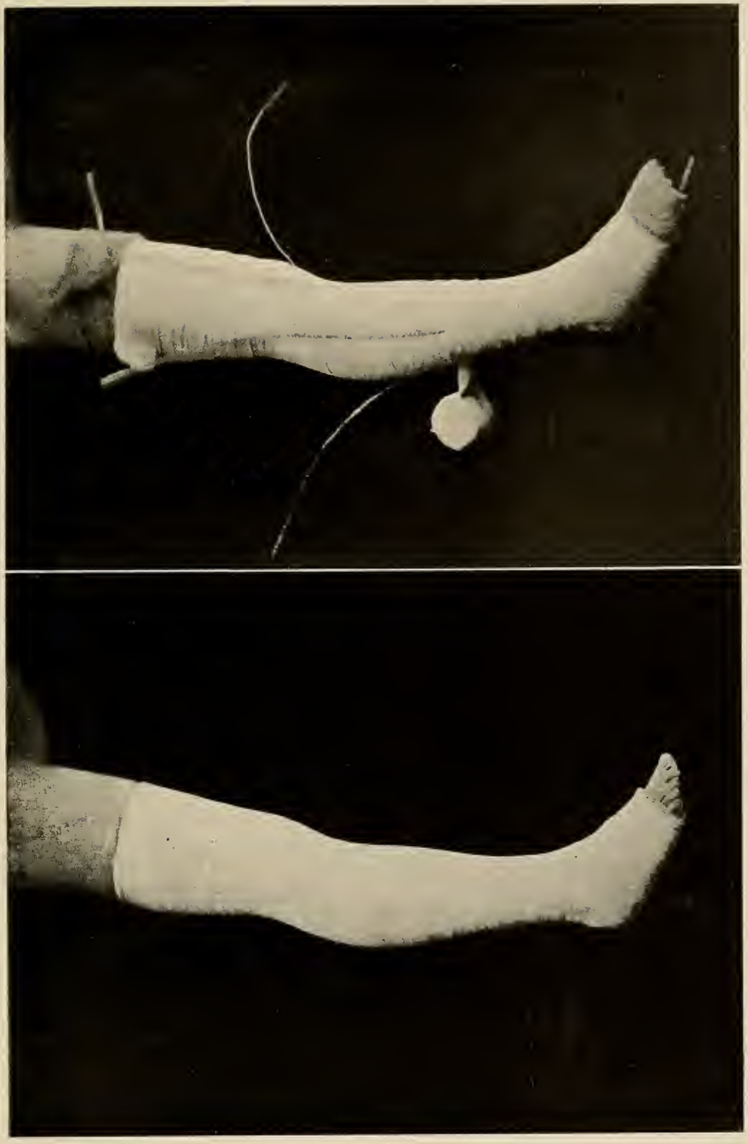

PLATE II.

Rapid Immobilization of the Broken Bones of the Leg.

Upper Figure.—Tin strips bandaged in relation to the lower fragment as far as site of fracture.

Lower Figure.—Finished splint. Strips bandaged in position without deforming the outline of the limb.

and allowed to hang free, and thus adapt themselves to the contour of the limb as the bandaging progresses. The strips having been firmly secured to the lower fragment as far as the point of false motion at the site of fracture, the surgeon then carefully directs his efforts to correcting the existing deformity. The guides to effect the attainment of this object have not been obscured and the conditions for making a correct adjustment are of the best; the outline of the limb has been preserved sharp and distinct; there is no obstacle to the exercise of the touch or the use of measurements.

Under the direction of the surgeon the assistant now exerts the full force of extension. The surgeon then makes the necessary corrective manipulation to overcome any angular or other deformity and while these procedures are continued in full play, he rapidly extends the turns of bandage upward fastening the exposed free portions of the strips home to their base and in relation to the upper fragment. As soon as this is done, which takes only a brief fraction of time, a few seconds, the fragments are firmly held in their given adjusted relation. Moistened plaster is rubbed into the layer of bandage as was the case with the first layer.

The ends of the tin strips extending beyond the margins of the splint are trimmed to a length of two or three inches, turned back upon the splint together with a finishing turned over cuff of the protective covering, and secured by plaster-of-Paris bandage.

While the splint should be strengthened by lengths of plaster-of-Paris bandage, or pieces of old blanket

saturated with a thin cream of plaster-of-Paris, bandaged into position, in places especially exposed to injury during the wear of a month's or six weeks' duration, it should not be made so thick over the portions of bones lying superficially and exposed to pressure, but that if required, undue pressure may be eased in such places by pressing the hardened splint between the hands.

The splint is finished (see Plate II) by rubbing into its surface moistened plaster and smoothing the same with rather wet hands. This finishing process should not be continued too long, otherwise it will disturb the initial set of the plaster and cause it to "flour."

When the splint is finished the patient is replaced upon his bed till the splint hardens.

The exposed toes are carefully watched as the tell-tale of the condition of the circulation. Being assured that the circulation of the limb is in safe condition, the surgeon should induce the patient to leave his bed and walk with crutches as soon as possible.

In the treatment of compound fractures of the leg strict antiseptic measures should, of course, be practiced. All compound fractures due to injury should be regarded as infected and the surgeon should never hesitate for a moment to enlarge the wound communicating with the fracture to insure its complete disinfection. Ample drainage of the wound should be provided for under such circumstances. In place of the protective covering of thin blanket an antiseptic covering material should be specially

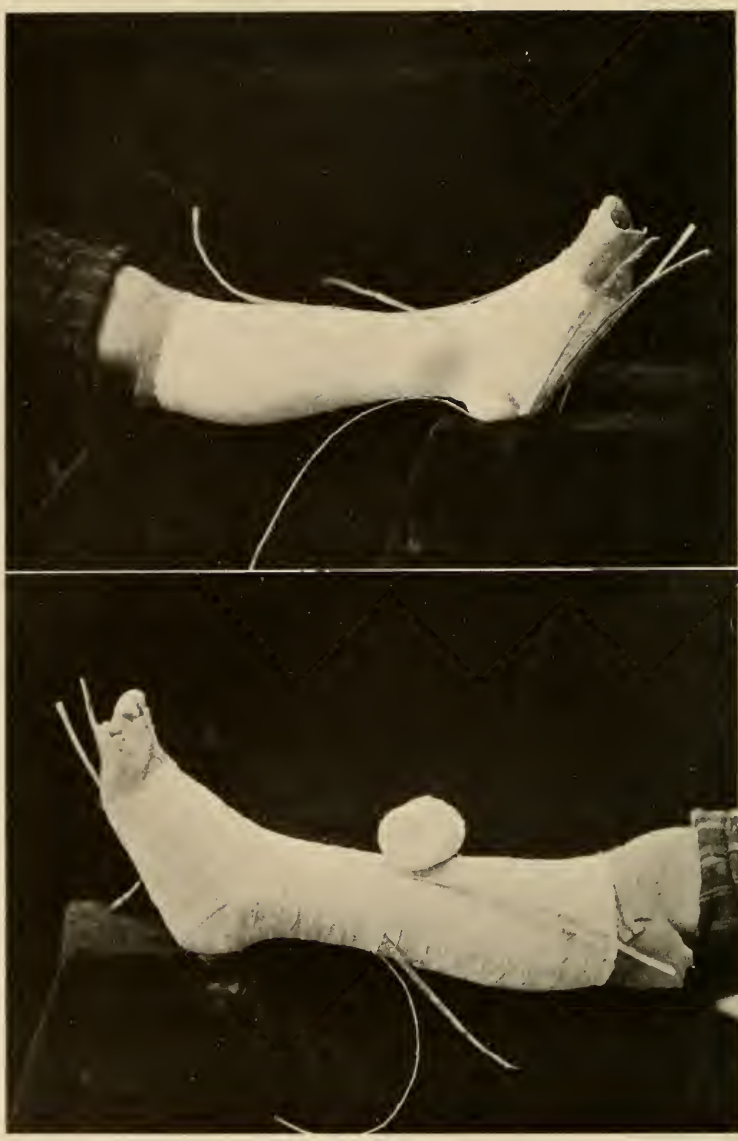

PLATE III.

Pott's Fracture near Ankle-Joint.

Upper Figure.—Tin strips in position upon a foundation layer of plaster-of-Paris bandage.

Lower Figure.—Tin strips being bandaged in position.

prepared. This may be made of a layer, not too thick, of antiseptic cotton, held between layers of antiseptic gauze (bichloride) and quilted. The tin strips are, of course, sterilized by immersion in an antiseptic solution or by heat. The original Lister antiseptic bandages, somewhat gummy from the resinous combination used in their construction, are highly useful. Bichloride bandages will, however, answer the purpose. The tin strips are bandaged in position in the same manner as if plaster-of-Paris bandages were used. After the fragments have been immobilized, layers of antiseptic gauze are bandaged about the region of the wound in sufficient quantity to absorb the secretions regardless then of deforming the outline of the limb. If desired, a more permanent character may be given to the retentive apparel by applying plaster-of-Paris bandages over all.

The author emphasizes the importance of using antiseptic instead of sterile dressings to absorb the wound secretions. Sterile dressings saturated with such secretions and held in contact with warm tissues furnish ideal conditions for germ growth. The use of sterile dressings in septic surroundings instead of antiseptic dressings to absorb wound secretion is in the author's judgment an unjustifiable procedure.

In a Pott's fracture with displacement of the foot, one of the tin strips is so placed as to correct the deformity, secure inversion of the foot and prevent motion in the plane of displacement. Said tin strip starting upon the sole of the foot is reversed at the heel so as to take a course diagonally across the

anterior aspect of the ankle in a direction from within outward, as shown in Plate III.

In a fracture of the humerus the tin strips may be applied as shown in Plate IV, if the use of an immovable splint is thought to be desirable, which, however, has only exceptionally been the author's practice. It is to be noted that the immovable plaster-of-Paris splint, except in skilled hands, is a highly dangerous apparel for fractures in the upper extremity, where the delicate soft tissues are extremely intolerant of pressure. The author has been called upon to amputate limbs in a number of instances of traumatic gangrene caused by too tight bandaging, but most frequently in cases of faulty bandaging of the arm and forearm. Curiously, none of these mishaps has been encountered in instances of application of the plaster-of-Paris splint.

In the treatment of fractures of the shaft of the femur more forcible extension to overcome the shortening of the limb must be employed than in the case of fractures of the leg, in which manual extension, with or without anæsthesia, suffices to overcome the moderate amount of shortening.

It will be instructive to briefly trace the evolution of the special apparatus for the setting of fractures of the femur in the plaster-of-Paris splint in use in Bellevue Hospital during the seventies, when under the great emulation in the practice of treating fractures in such splints the art was brought to the highest pitch of perfection by the House Staff of the hospital.

At first, counter extension was made from a

PLATE IV.

Left-hand Figure.—Fracture of the Shaft of the Humerus. Tin strips in position upon foundation layer of plaster-of-Paris bandage.

Right-hand Figure.—Finished Splint, showing preservation of the outline of the limb.

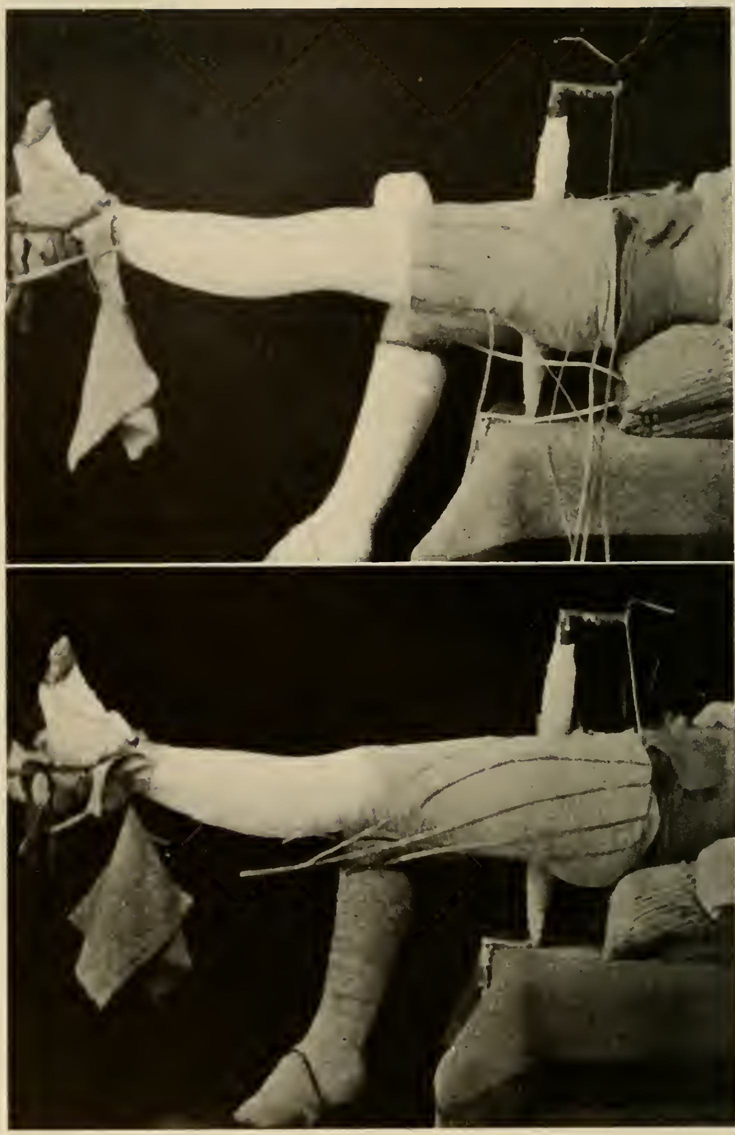

PLATE V.

Setting Fracture of the Shaft of the Femur with Tin Strips and Plaster-of-Paris Bandages. The patient has been moved from his bed to the operating-table.

Upper Figure.—Tin strips bandaged to foundation layer of plaster-of-Paris bandage as far as the site of fracture.

Lower Figure.—Strips reversed downward from upper margin of the splint.

straight upright perineal bar clamped to the edge of a table. (See Plate V.) The patient was anæsthetized in his bed, then transported to the table, and while prone was placed astride the bar. His pelvis was suspended by a folded sheet looped from a narrow strip of wood, one end of which rested upon the end of the perineal bar and the other upon a stool or other support placed upon the table, beyond the patient's head. The wood was always in the way of the anæsthetizer and frequently slipped from position. One of the House surgeons substituted a bandage for the sheet to suspend the patient's pelvis. The bandage at the middle of its length was tied to the perineal bar at about the place the perineum would bear; about six inches from the bar it was knotted together, the ends to be brought along each side of the pelvis and attached to the overhead strip of board. This bandage, suspending the pelvis, was built into the splint during its construction and was sometimes withdrawn when the splint was completed, otherwise it was simply cut close to the splint, when releasing the patient from the bar. The first improvement made by the author dispensed with the troublesome overhead strip of board altogether, by bending the upper portion of the perineal-bar at a right angle and extending it about five inches horizontally over the pelvis with a short lip or projection on its upper surface, thus making the point of suspension integral with the bar itself.

Under the great tractive force exerted by means of the compound pulleys, the bracing of the table would yield, or the edge of the table would some-

times break. Furthermore, there was still the necessity of transporting the patient back and forth from his bed to the operating table with the chance of a considerable disturbance of the broken limb while in transit. In one patient under the author's observation, but not in his practice, the bending of the limb during the struggles of the patient caused the fragments to lacerate the femoral vein, resulting in his death. The imperfect means of counter-extension, the necessity of transporting the patient, and the possible accidents incident thereto, led the author to devise the construction which he used ever after with the greatest satisfaction and without the occurrence of the slightest accident.

The apparatus could easily be made more portable for use in military practice.

The contrivance, inexpensive and easy of construction, consists of a perineal-bar fixedly mounted in a wooden tripod as shown in the frontispiece. The perineal-bar is made of a length of half-inch of five-eighths of an inch bore gas-pipe projecting above the centre wooden block or body of the tripod into which it is securely fastened. Into the free upper end of this pipe is received for five or six inches a smaller pipe which extends about six inches above the larger pipe or perineal-bar and which is then bent to extend horizontally about six inches, terminating in an upturned lip. This piece is removable and taken out when the patient is being placed astride the perineal-bar. When fitted into the larger section of pipe it holds its position by friction, the portion sliding into the perineal upright is slightly bent out of

its long axis so that it will hold by friction when fitted into place. The perineal-bar is cushioned where the perineum will bear, by being wound with a strip of blanket or other material held in place by dry bandage. It is advisable, for reasons that will be given later, not to cushion the perineal upright to a great thickness with the idea of saving the urethra from pressure.

In older practice with the original perineal-bar, operators sometimes padded the bar to a great thickness, often to two inches or more in diameter. This of necessity brought pressure upon the middle line of the perineum. But even with this faulty practice no harm ever came to the urethra. The bar of smaller diameter, however, may be crowded against the injured thigh past the middle line, thus saving the urethra from pressure. A sufficient length of medium-sized copper wire is fastened at its middle to the perineal-bar at about the place the patient's perineum will have a bearing when he is in position; the strands of this wire are twisted together for about six inches and then allowed to hang free. Its use will be stated subsequently.

No bloodless operation comes to the writer's mind that requires more skill in its successful performance than the setting of a fracture of the shaft of the femur in an immovable splint. Errors of skill in the application of a movable splint may be corrected during the early stages of treatment, thereby averting the evil consequences of mistakes. In applying an immovable splint, however, all the skill necessary to eliminate the consequences of mis-steps must be con-

centrated in less than an hour's work. As an illustrative instance we will take for treatment a supposed patient with a recent simple oblique fracture of the shaft of the femur at the middle of its length with marked shortening of the limb.

The immovable apparel should be applied as soon after the patient has reacted from the shock of the injury as the condition of the limb in reference to swelling, will allow. The nearer the application of the splint to the time of the receipt of the injury, the more easily can a correct adjustment of the bony fragments be made.

The time of setting a fracture in relation to the time of the occurrence of the injury is a factor of prime importance. This was well shown by many instances of suture of simple transverse fractures of the patella by open operation either performed or witnessed by the author. In patients operated upon very soon after fracture, the fragments could be drawn together and held in position by a very slight force. After delay, however, the fragments were difficult to approximate and it required a stout suture to hold them together. The very early operation gave to the surgeon an extended choice of character of suture; procrastination greatly limited that choice.

Upon the same principle the early treatment by the surgeon (the earlier the better) enables him to adjust the broken long bone in position, especially in fractures of the shaft of the femur. The illustrations (Plate XVIII) show a sample of simple fracture of the lower third of the femur of greatest obliquity treated very soon after fracture in which the union

of the broken bone was obtained in best position. Traction easily restored the length of the limb. On the other hand, in an instance of mal-union with over four inches of shortening, the most forcible efforts at reduction, which were made immediately after a refracture, only slightly diminished the shortening of the limb. The soft parts, muscles, tendons and especially the fibrous skeleton of the thigh had grown in accommodation to the new condition of shortening of the limb and the contractures could not be corrected by sudden and great tractive efforts. It is in such instances that long-continued traction would appear to be allowable in an attempt to correct the confirmed shortening.

The illustration (Plate XVIII) shows further the capacity of the immovable apparel to maintain extension and counter-extension for a length of time sufficient to achieve union in perfect position of the fragments. That the immovable plaster-of-Paris splint does exert extension and counter-extension was well shown in an instance witnessed by the author in which the splint was light and weak, no tin strips having been used, and when the extension by the compound pulleys was relaxed while the splint was green and soft, it telescoped at the site of the fracture to the extent of the amount of the shortening. Extension by the compound pulleys was immediately reapplied, the telescoping of the splint at the site of fracture was removed, the splint was made of due strength and a satisfactory union of the fragments was obtained.

The usual controlling local condition is the swell-

ing. While it is true that the plaster-of-Paris splint may be applied at any time irrespective of the degree of swelling, it can only be used as a continued or permanent apparel developing its maximum efficiency, while the size of the limb remains comparatively stationary. A confining and constricting bandage has little control over a rapidly increasing swelling. Certain necessitous circumstances may be conceived and do occur, especially in fractures of both bones of the leg, when the application of the splint is imperatively demanded, notwithstanding the presence of advancing swelling.

If the swelling be acute and increasing, the applied splint must immediately be cut open and eased or the constricted limb, perhaps the life of the patient, will be sacrificed. On the other hand, if a considerable swelling be rapidly subsiding, the splint will soon be a loose fit and ineffective and need reapplication. In either instance the splint as applied will be only a temporary apparel, the maintenance of its efficiency with safety requiring successive reapplications.

If the trained judgment assures the surgeon that the swelling will be slight and the changes in the size of the limb negligible, the splint may be applied as a permanent fixation apparel very soon after the occurrence of the fracture—the sooner the better. Generally, however, the elective period of its application as a permanent apparel is that of greatest safety consistent with efficiency, namely, when the swelling has passed its maximum and in recession has reached a comparatively stationary limit, which usu-

ally is a matter of a few days after the receipt of the injury, the limb meanwhile, of course, having been under continual extension with weight and pulley.

The amount of shortening of the limb from the fracture is ascertained by carefully made measurements. In measuring the limb the operator avoids prejudice and deceiving himself by having the blank side of the measuring-tape turned toward him. He measures from the anterior superior spine of the ilium to the tip of the inner malleolus, the patient's pelvis meanwhile being perfectly squared, so that an imaginary line drawn transversely through the anterior superior spines of the ilia meets the median longitudinal plane of the body at a right angle. For confirmation, the measurements are repeated. Not all surgeons are capable of making reasonably exact measurements. One prominent surgeon known to the writer would commit gross errors; the amount of his personal error was, indeed, sometimes as great as the amount of the shortening to be measured. With such errors inherent in the personal instrument the measurements were of course fallacious.

The patient is then prepared for anæsthesia. Inasmuch as the degree of swelling is a large factor affecting the mechanical efficiency of the splint, the limb should at all times be carefully guarded against a disturbance of the soft parts. While the use of an anæsthetic is highly desirable, it is not absolutely essential. With old and very feeble patients a stimulant may be used instead. The writer has known his skilful and rapidly working assistant to complete

the whole operation in a most excellent manner in less than half an hour.

The fractured limb should be most carefully protected against injury preparatory to the administration of the anæsthetic. Temporary splints should be applied and extension meanwhile maintained. In addition assistants should safeguard the patient, a particularly trustworthy one having constant charge of the broken thigh. The patient when anæsthetized to complete relaxation should be held continuously in the same degree of anæsthesia throughout the operation. This, like all well-conducted, important and complicated surgical operations, should be constantly supervised and coördinated by the operating surgeon.

The patient being fully under anæsthesia, the operator removes all dressings from the limb, an assistant, of course, constantly maintaining manual extension. Other things being equal, the operation to be well done should be speedily done. Even minutes should be economized. In the complex operation which we are describing, careful forethought and method in executing the different steps of procedure will in the total economize the time and shorten the period of anæsthesia. This is all the more desirable since it is not necessary to give time for the setting of the plaster-of-Paris, under the anæsthetic, the fixation of the fragments being immediately accomplished by the action of the tin strips when bandaged in position.

A transverse mark is made upon the skin above the inner malleolus of the injured limb, which will

serve as a point in measuring to correct the shortening of the limb.

The protective covering of thin blanket or other material is carefully slid beneath the patient. One free edge of the material which extends a short distance beyond the injured limb is cut to conform to

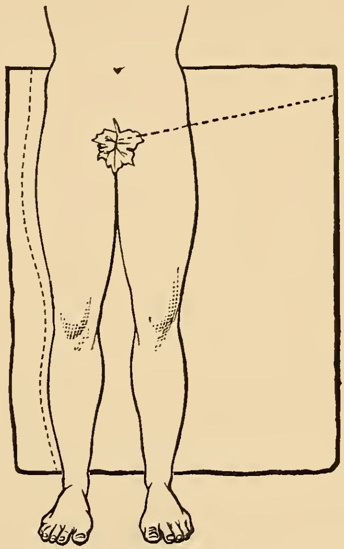

Fig. 2.—Plan of Cutting Blanket Covering of Thigh in Fracture of Shaft of Femur.

the middle of its external surface (Fig. 2). This is done by first making a number of guiding cuts in the edge of the blanket. Beginning near the ankle, with one hand the flap of blanket is held against the middle line of the external aspect of the limb and is then cut with scissors down to that point. At intervals of a few inches similar cuts are made in the blanket along the whole length of the limb

and that portion of the pelvis that is to be covered. The superfluous blanket, as shown by the guiding marks, is cut away till the edge of the blanket, perhaps with a little trimming, can, when brought into position, be made to reach to the middle of the external aspect of the limb throughout the whole length to be covered. The patient's healthy thigh is flexed at a right angle with his body, and the other portion of blanket is cut diagonally from above downward to a point opposite the anus. This cut is so made that the portion of blanket above the cut may be brought around the pelvis anteriorly and temporarily held in position with a single pin.

The lower or thigh portion of blanket, below the transverse cut, is brought across the inner and anterior surfaces of the injured limb, especial care being taken to cover the groin and perineum. This portion of blanket is trimmed to guiding cuts, as was the case with that covering the posterior and outer surfaces of the limb. The blanket covering the inner and anterior aspects of the limb overlaps that covering the posterior and outer aspects, the fold thus formed lying along the external and less important aspect of the limb, and is pinned in position beginning at the ankle. The loose edge of the fold thus placed does not obstruct bandaging, but is easily fastened in position by the successive turns of the bandage. It is better to fasten the protective covering by common pins than with needle and thread. Little changes may then be made to make the perfect fit and the pins may be removed as the turns of bandage fasten the covering in position.

The foot need not be covered till the splint is finished but during the operation the blanket for covering the foot may be left loose and turned back from the ankle, out of the way. The protective covering of the thigh and pelvis has been adapted while the patient has been lying in bed under anæsthesia, the assistant meanwhile preserving the manual extension upon the limb; it having been so snugly and neatly applied that the outline of the limb has not been obscured or changed. The patient is now ready to be placed upon the special apparatus necessary for extension and counter-extension to facilitate the construction of the splint.

It will be observed that the power (the compound pulleys) is located between two fixed points, the two inserted screw-eyes, the one from which extension is made, and the other, the fixed point of counter-extension. The patient is not so immovably fixed upon the apparatus but he may shift from position. He is so conditioned, however, that for a sufficient though brief time he may be held in the desired position of best adjustment of the fragments. The assistant exerts control over the upper fragment through acting upon the long arm of the lever resting upon the perineal-bar as a fulcrum. The same assistant controls the rotation of the lower fragment. The surgeon avails himself of all helps to secure correct adjustment of the fragments, that is, he coördinates all the elements necessary to secure that end, and then, while the patient is in position of election, quickly immobilizes the fragments.

The surgeon locates an imaginary vertical plane cutting the bed at a right angle at about the middle of its length, which may be designated the plane of counter-extension. (See Ground Plan, Fig. 3.) In this plane, beneath the edge of the bed, is inserted at a slight angle in the floor a strong screw-

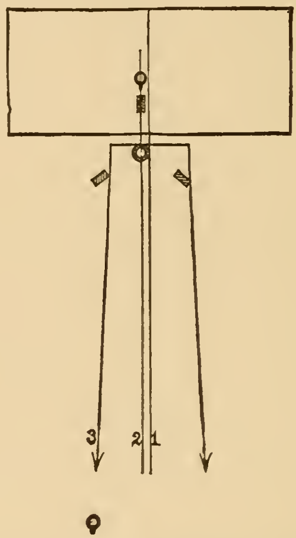

Fig. 3.—Ground Plan of the Position of the Patient upon the Apparatus in the Application of a Plaster-of-Paris Splint in the Rapid Setting of a Fracture of the Shaft of the Femur. No. 1 is the median plane of the body. No. 2 is the plane of counter-extension. No. 3 is the plane of extension.

eye which constitutes the fixed point of counter-extension. The small piece of gas-pipe fitting into the upper end of the perineal-bar serves well in inserting the screw-eye into the floor. The movable tripod, minus the smaller pipe, to be inserted later into the upper end of the perineal-upright, is

brought near the edge of the bed, the rear leg extending under the bed, being located in the plane of counter-extension three or four inches from the inserted screw-eye; the other two legs of the tripod (forward legs) are placed equidistant from this plane, on either side respectively. A rather heavy copper wire is caught at its middle over the screw-eye in the floor and then very coarsely twisted together till it reaches the upper surface of the centre block of the tripod. The ends of wire are wrapped about the upright perineal-bar in opposite directions and made fast by twisting (see Frontispiece). By means of this twisted wire the perineal-upright is hitched fast to the screw-eye and is constituted an unyielding resistance of counter-extension. In other words, the fixed point for counter-extension is transferred from the screw-eye in the floor to the perineal-bar at the place of bearing of the perineum. By pulling upon the perineal-bar any slack in the wire is removed by stretching, and the forward legs of the tripod which oppose a counter-resistance under extension are made to stand squarely upon the floor.

The principal assistant, always continuing his extension upon the injured thigh, seizes the patient by both ankles while the anæsthetizer grasps him by the shoulders and, acting in concert, under supervision of the surgeon, they pivot the patient upon the bed bringing the sound limb first toward the perineal-bar. The sound thigh is sufficiently flexed that it may be lifted over the end of the bar and the patient so placed in position that the median

longitudinal plane of his body shall be carried as far as possible in the direction of the uninjured side, at the same time being maintained parallel to the plane of counter-extension.

The purpose of this is to increase the leverage upon the upper fragment when traction is made upon the uninjured limb, the perineal-bar acting as the fulcrum upon which the pelvis may be tilted. The further the median longitudinal plane of the body is crowded over in the direction of the uninjured side the greater will be the leverage and command over the upper fragment. Added to this advantage, the pressure will be away from the median line of the perineum, the urethra thus escaping, and furthermore, a less total pressure will be exerted upon the perineum.

The patient having been properly placed in position it now becomes an additional duty of the anæsthetizer, under supervision of the operator of course, to assist in the preservation of the patient in correct position.

The smaller pipe fitting into the upper end of the perineal-bar is then fitted into place. The bed is pushed back from the perineal-bar just far enough to give working space about the patient's pelvis. The copper wire, previously attached to the perineal-bar, is carried backward along the sacrum and the ends are brought upward along each side of the pelvis and attached over the tip of the horizontal piece of the smaller pipe of the perineal-bar overhanging the pelvis.

The purpose of this wire is not so much to sus-

pend the pelvis as to prevent its displacement by partial rotation on a longitudinal axis of the body projected through it to its bearing against the perineal-bar. It is therefore a guy-wire. The pelvis is sustained clear of the bed by the patient's body resting upon the bed and by being held firmly in its bearing against the perineal-bar under the force of extension. Ample working room may be gained about the pelvis by pushing the bed back from the perineal-bar, without disturbing the adjusted position of the patient upon the apparatus. A clove-hitch made sufficiently strong from a folded bandage is now attached to the naked ankle above the malleoli. The ends of the bandage are tied into a loop into which may be caught one of the hooks of the compound pulleys. The clove-hitch may be so adjusted to the ankle that it will, in large degree, control the eversion of the lower fragment.

The fixed point from which extension is to be exerted is constituted by a strong screw-eye which is screwed into the woodwork of the room at a point where the prolonged long axis of the broken limb under extension will touch.

Before the operation has been commenced, the bed has been placed in proper position in reference to the mechanical requirements of the operation and the screw-eyes inserted in proper position.

As shown in the Frontispiece, the principal assistant, comfortably seated, with one hand controls the rotation of the lower fragment by so holding the ankle that the foot is somewhat inverted; at the same time grasping the ankle of the uninjured

limb he exerts sufficient traction to hold the pelvis in position and control the upper fragment. The importance of so placing the pelvis upon the perineal-bar as a fulcrum as to favor the leverage upon the upper fragment has been explained. Sometimes a clove hitch is attached to the ankle of the uninjured limb and connected to the extension upon the other limb, but with a trained skilful assistant exerting control over the upper fragment this feature of practice may be generally dispensed with.

We may pass in review the steps of the procedure to the present stage of the operation:—

The patient lying upon his bed has been protected from self-injury during the administration of the anæsthetic by having temporary splints applied to the injured limb.

The anæsthetic has been given. If the patient is old and feeble a stimulant may be given instead.

The temporary splints have been removed and the limb and pelvis covered with a protective of thin blanket or other material.

Imaginary planes have been located for the guidance of the surgeon in placing the patient upon the special apparatus.

The fixed points for extension and counter-extension have been established and the special thigh setting apparatus has been placed in position.

The patient has been placed upon the apparatus and the extension by means of compound pulleys has been substituted for manual extension which has hitherto been constantly exerted.

All through the procedures the injured limb has

been disturbed as little as possible so as not to excite an increase of swelling.

Enough extension is for the time exerted through the compound pulleys to straighten the thigh and take out most of the sag at the place of fracture. All through the operation the surgeon strictly coordinates his assistants, supervising, with a full sense of his responsibility, every feature of the operation. All preparations that forethought could suggest have been made so that there may be no delay in the progress of construction of the splint.

As in the case of the leg splint, a foundation layer of plaster-of-Paris bandage is applied to the leg, thigh and about the pelvis covering the limits of the prospective splint from the ankle to the pelvic limit. Especial care is bestowed in the making of the spica at the pelvis. One layer of bandage even when closely imbricated does not make a sufficiently firm foundation for the tin strips especially with the yielding soft tissues about the groin. There, and at any other place where the underlying soft tissues are too yielding to give a good basis for the tin strips, either strips of plaster-of-Paris bandage folded in reverses, or pieces of blanket saturated with a thin cream of plaster-of-Paris and cut to form will remedy the weaknesses. Into the foundation layer, as in the construction of the leg splint, a small amount of moistened plaster is rubbed, smoothing all folds of bandages and sticking them together. This foundation layer, when completed, leaves the outline of the limb sharp and distinct.

The pelvic portion of the splint should not be extended too high. The author has sometimes seen it made so high as to infringe upon the lower ribs, thus greatly hampering the movements of the patient, who could not even sit up in comfort. The pelvic portion of the splint is for the purpose not only of securing a hold upon the upper fragment, but also for the purpose of controlling the rotation

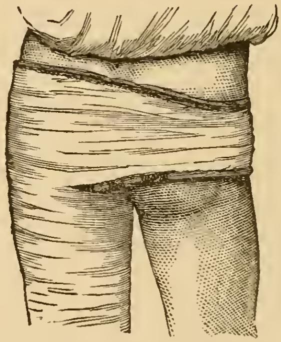

Fig. 4.—Construction of Pelvic Portion of Thigh Splint (rear view) in Fracture of the Shaft of the Femur.

(generally in eversion) of the lower fragment. The proper construction is shown in Fig. 4.

The weak places where the splint is most likely to give way from the wear of weeks are about the groin, the buttocks, and the posterior aspect of the thigh and leg. In construction, the strength of the texture of the splint is proportioned somewhat to the closeness of the imbrications of the folds of bandage.

The tin strips for use in fractures of the shaft of the femur are made no wider but longer than need

be the case for fractures of the leg; otherwise they are of the same construction. They are easily made longer by soldering two or more strips together at their overlapping ends. About seven or eight strips are used, and they are disposed in the principal longitudinal planes of the limb as in the case of setting the leg fracture, described. To reiterate, the tin strips operate as a resistance to forces by reason of their not changing in length, either by shortening or lengthening when nicely adapted to the contour of the surface of the limb and firmly held in position between layers of bandage. They resist forces tending to displace the fragments in shortening of the limb or in angular deformity, rotation or any other mode of displacement that can be resisted from the surface, operating upon the bony fragments through the yielding medium of the soft parts: they also develop some resistance by virtue of their width, though very narrow.

While they, no doubt, add to the strength of the constructed plaster-of-Paris splint, their use was not designed for that purpose. They are themselves the splint, constituting the resistance to forces tending to move the fragments in relation to each other, immobility within limits being the essential attribute of all methods of treatment. Their action, *immediately operative,* is rendered more surely *permanent* by the material used in the bandages by which their primary and essential function is continued. The plaster-of-Paris splint in its construction is an infinitude of lines of resistance coming into practical operation through the hardening of

the plaster, which requires the lapse of a variable period of time; the tin strips develop their resistance immediately.

To proceed with our operation, tin strips are placed on either side of the anterior median line and in the posterior median line and side strips, internal and external, midway between them. Added strips are placed anteriorly and posteriorly between the median and lateral strips. They extend from the ankle to a line far beyond the designed upper pelvic margin of the splint. They are held in position by a few turns of the bandage at the ankle till their correct general course up the limb is assured. The tin strips are firmly bandaged home to their foundation as far as the site of fracture. During the whole bandaging the exposed portions of the strips are allowed to hang free and uncontrolled that they may adapt themselves perfectly to the contour of the limb.

When they have been bandaged firmly in relation to the lower fragment as far as the site of fracture, the surgeon carefully reviews the situation. He makes sure that the patient is in every respect in correct position upon the apparatus. With his tape he measures from the anterior superior spine of the ilium to the mark made upon the skin of the ankle, at the same time directing the assistant holding the rope of the compound pulleys to make sufficient extension to overcome the known amount of shortening of the limb; it is well to even overcorrect the shortening. He carefully regards the outline of the thigh to see that all sag at the place

of fracture is removed, and that the normal outline of the thigh is restored, using any manipulation that may be necessary to secure that object. All this is done with a strict regard to the preservation of the patient in correct position upon the apparatus.

With a final word of warning to his assistants to be alert in the performance of their duties, he rapidly, in a few seconds, by figure of eight turns of the bandage, firmly bandages the tin strips home to their foundation and in relation to the upper fragment. By this rapidly executed manœuvre the fragments are fixed in their adjusted relation to each other. He continues his bandaging to the upper pelvic margin of the splint, where he reverses the tin strips sharply, bringing them down again upon the splint (see Plate V, lower figure) in a direction downward and diagonally outward. Most of the reversed strips reach down past the site of fracture. The anterior strips he cuts short before the knee-joint is reached. The posterior strips and some of the lateral ones reach down past the knee-joint upon the calf of the leg. The reversed strips are not allowed to interfere with each other; they hang free and uncontrolled and are bandaged home from above downward, commencing at the upper pelvic margin of the splint. The fixation of the adjusted fragments, although the splint is wet and soft, has been accomplished under the best conditions. The guides for correct adjustment have not at any time been obscured or impaired.

The surgeon may now proceed to strengthen the

splint without any fear of disturbing the adjusted fragments, now already fixed in their relation to each other. A little experience will teach just how much and where the splint should be reinforced posteriorly to stand a month's or six weeks' wear. A skilful hand may so manipulate the plaster-of-Paris bandage in making reverses to give all the added strength in places otherwise weak, that is required, or, pieces of thin blanket saturated with plaster-of-Paris cream and cut to form, may be bandaged in position. The protective covering of blanket extending beyond the pelvic margin of the splint is then trimmed to within two or three inches of the margin of the splint, turned back upon it as a cuff, and retained in position by plaster bandages and finally, while quite wet, moistened plaster may be rubbed into the entire surface of the splint. This finishing coat should not be too thick, nor should the smoothing process be too long persisted in, lest, to repeat, the initial set of the plaster be interfered with, and the plaster "flour."

The construction of the splint having been thus far completed, extension is relaxed, the compound pulleys disconnected, and the clove-hitch removed from the ankle. The protective covering having previously been cut to form, the foot and ankle are speedily covered, the covering of the foot having been so well arranged that it may be retained by a single common pin. This covering is so adapted that the instep and tendo Achillis are covered by a double layer.

In bandaging, care is exercised that the dorsal

face of the instep, the point of the heel and the skin over the tendo Achillis are not subjected to an excess of pressure. From the lack of exercise of skill in this regard the author has seen an ulcer upon the heel give more trouble than the cure of the fracture itself.

It is always to be remembered in bandaging that the greatest support to the circulation by compression is to be given to the periphery of the body, the strength of compression lessening as it approaches the circulatory centre. The foot may be simply bandaged with an ordinary dry bandage, but the author's preference and general practice has been to use the plaster-of-Paris bandage.

Some surgeons in applying splints that include the foot have been at great pains to immobilize the foot at right angles with the leg. The reasons for this practice seemed to the author to lack force. It is an unnatural position of the foot and there is a greater risk involved from unequal and undue pressure. It has never been practiced by the author whose results have always been without the complication of accidents, and perfectly satisfactory.

The inclusion of the foot and ankle in the constructed splint while not absolutely necessary, is generally advisable. The construction of the splint upon the foot and leg, preliminary to the making of the thigh splint should never be practiced. When extension is made from the leg piece of splint already applied it is liable to slip and the leg splint will then act as a partially withdrawn tight fitting boot, causing undue pressure at certain places, with

great discomfort and probably troublesome sloughs. Neither should the toes ever be covered in, as the author has sometimes witnessed. The exposed toes are the tell-tale of the condition of the circulation. They should be always left free.

The patient is now ready to be freed from the apparatus. It will have been observed that while upon the apparatus the patient has always been in the best position for surgical functioning, no restrictions having been imposed thereon. At any stage of the operation, should necessity therefor have arisen, he could easily have been freed from the apparatus. This could have been done in a few seconds' time and the patient replaced in bed in his original position. The anæsthesia is stopped. The heavy wire connecting the tripod to the screw-eye of counter-extension is untwined; in an emergency, to gain a few seconds of time, this could be cut with strong scissors. The guy wire controlling the rotation of the pelvis, is cut on either side. The patient is seized by the shoulders by the anæsthetizer and drawn a short distance up on the bed. While the anæsthetizer holds the patient by the shoulders and the first assistant holds him by the ankles, the tripod, its forward legs resting upon the floor, is pulled over, withdrawing the pelvic guy-wire from the splint, and the patient then rests upon the bed, thus speedily freed from the apparatus. The two assistants, protecting the splint as much as possible, turn the patient as upon a pivot, back into his original position upon the bed.

After the splint has set and hardened, and before

it is dry, the surgeon carefully inspects his work. First of all, he notices the character of the circulation. With a snug fitting splint the toes may be at first a little puffy, but the circulation must be distinct, bright and not retrograding. If complaint is made of pressure over bony points it may be eased by compressing the splint between the hands. Continued complaints of pain should never be masked with morphine but must receive respectful attention, even if it results in the cutting down of the splint. Under such circumstances the surgeon will wish he had moderated the pressure of his bandage in the affected places, which attainment was within the reach of skill. He specially directs his observation to the delicate tender tissues of the perineum. In a well-constructed splint, it may happen that he will be obliged to trim away the edge of the splint there, but he should be very slow in taking away too much splint and leaving the tissues unsupported, otherwise they will "bag," become congested and ulcerate at the margin of the splint. At first he may do a little trimming in the perineum down to the blanket protective covering. On the contrary, it will sometimes happen that he has not carried his construction far enough or, perhaps, he has cut away too much of the splint upon the perineum and that the tissues will bag. To correct these conditions and the tendency to ulceration he should not cut away the splint but support the tissues with a well-applied dry bandage applied over the splint, perhaps even slightly padding the concerned supported tissues.

All going well, the surgeon induces the patient to move about as soon as possible. The operation has been conducted in such a manner as to irritate the lacerated soft tissues as little as possible thereby forestalling any disagreeable reaction in the way of increased swelling. The compressing splint holding the fragments comparatively still, and withdrawing the injured muscles from functioning, beneficently quiets the tissues. At the same time it must be remembered that a continued shrinkage in the size of the limb alters its physical and mechanical relations to the splint, lessening the resistance of the latter to forces tending to move the fragments. Consequently it is desirable, for mechanical reasons alone, to induce the patient to move about so that the ensuing local œdema may keep the splint packed and efficient as a resistance.

Within forty-eight hours, perhaps the next day, the patient is urged to leave his bed to sit in a chair and be propped up with pillows. Very soon, within a day or two, he walks upon crutches, not, of course, bearing any weight upon the injured limb. In about a month, perhaps a little sooner, the patient himself subjectively knows that union of the fragments is well established. At the end of a month or six weeks, the splint, pretty well worn, is cut down anteriorly. A strip is moistened with water in the anterior median line and cut down with a common knife with rather a coarse cutting edge. Tin strips, as they are encountered, are cut with stout scissors. Specially designed instruments to cut down the splint are of little worth. When

the splint is removed, of course, great interest centres in the amount of shortening of the limb. Comparative measurements with the healthy limb are taken and recorded.

When the use of the immovable plaster-of-Paris splint in the treatment of simple fractures of the shaft of the femur was much practiced, I think I am safe from contradiction and very moderate in making the general statement, that in expert hands such treatment was at least as effective in overcoming shortening as any other treatment then in vogue. Indeed, many times I have found experts in measuring, fail to find more than a negligible discrepancy between the two limbs, say $1/8$ or $1/4$ of an inch. And in some few instances I have heard an expert declare his doubt that the thigh had ever been broken and that he must have evidence that such had been the fact, when of course it could be amply proven to have been the case.

After the measurements have been impartially taken, in the further treatment of the limb the splint is treated as a movable one. It is taken off as much as possible and used only when necessary to protect the limb against the chance of accidental injury. Every day the limb is douched alternately with hot and cold water, gently shocked, and function stimulated by the patient's exercise of his will and his own active efforts. Under such a line of treatment the stiffness of the joints rapidly disappears, the union is strengthened and the normal function of the limb regained.

To overcome the stiffness of joints in the treat-

ment of these injuries, as well as in the more aggravated instances after the open suture of fractures of the patella, the author has never practiced passive motion. Overlooking the arguments that might be made against it, he will declare that in all instances the active efforts of the patient under the stimulus of the will have been competent to restore full normal function to the joint.

From his experience and observation the author avers that under good treatment a non-union of the fragments must be a rare occurrence.

In the instance of the simple fracture of both thighs, shown in Plates X and XI, two perineal-bars were mounted in the wooden tripod instead of one, thereby avoiding pressure upon the middle line of the perineum. The lower limbs were brought to the same length and enclosed in splints. The constructed splints were heavy and anchored the patient immovable in bed. He at once began to lose appetite and strikingly to lose strength. To afford him a chance to exercise, the author rigged for him the suspension apparatus shown in Plates X and XI. The patient was at once delighted with it. Whenever he felt disposed, which was often, he would swing himself clear of the bed and exercise like an acrobat. One evening he suspended himself at eleven o'clock (as in Plate X), and after exercising fell asleep and slept soundly till breakfast time next morning. He soon recovered his appetite and rapidly regained his strength. While undergoing treatment he was taken in the ambulance to Bellevue Hospital, where he was exhibited

before the class of students. He was suspended from the great dome of the amphitheatre and took pleasure in going through his exercises. When the splint was removed the lower extremities were found to be without deformity and, by careful measurements, of equal length. Soon after he recovered function in the fractured limbs and went to his former work, earning his livelihood.

It has been stated that the degree of efficiency of the immovable plaster-of-Paris splint is related to the degree of compression of the soft parts. In some instances, where there has been great injury of the soft tissues, their tolerance of compression is very slight, with the consequence of a reduced efficiency of the resistance afforded by the splint. This is generally the case in compound fractures, and also in some simple fractures where, in spite of swelling, from special reasons, like imminent delirium, the protection of a splint is rendered necessary. Inasmuch as the line of safety in compression of the soft parts must not be transgressed, it becomes advisable to moderate the effect of forces tending to move or displace the fragments, which is tantamount to increasing the resistance afforded by the splint, and this is accomplished by the suspension of the injured limb. The better to understand the principles of suspension embodied in apparatus, it will be well to briefly trace the development of the suspension apparatus formerly in use in Bellevue Hospital.

The most primitive contrivance then in use was the suspension of the limb in splints by loops of

bandage from a cradle placed over the limb. This in a limited degree withdrew resistance in a single plane, principally acting upon the lower fragment.

A very decided advance was made by the device of Dr. Van Wagenen, a member of the House Staff. His contrivance consisted essentially of a wooden gallows, made fast to the foot of the bed. Its flat horizontal portion, overhanging the limb, contained two slots, each about six inches long. Upon an iron rod passing lengthwise of each slot travelled a pulley from which depended a few inches of rubber tubing, which carried at its lower end another pulley whose plane of rotation was transverse to the long axis of the suspended limb. The limb in splint was suspended in loops of rope which ran over the lower pulleys. In its action, this apparatus withdrew resistance to motion in a vertical plane, and also to rotation of the limb upon its longitudinal axis. In practice, however, the two upper pulleys would often approach each other, bringing the suspending loops of rope together, sometimes over the wound, and the even support of the limb in balance would be destroyed.

These defects, among others, led the author to design the construction shown in Plate VI, which in action was very satisfactory. A triangular wooden support was fastened to the foot of the bed. Into a socket in its upper end was received an iron gas-pipe, which turned freely. The pipe extended perpendicularly upward, and was then bent to extend horizontally. Into its free end was received a piece of smaller pipe, which extended

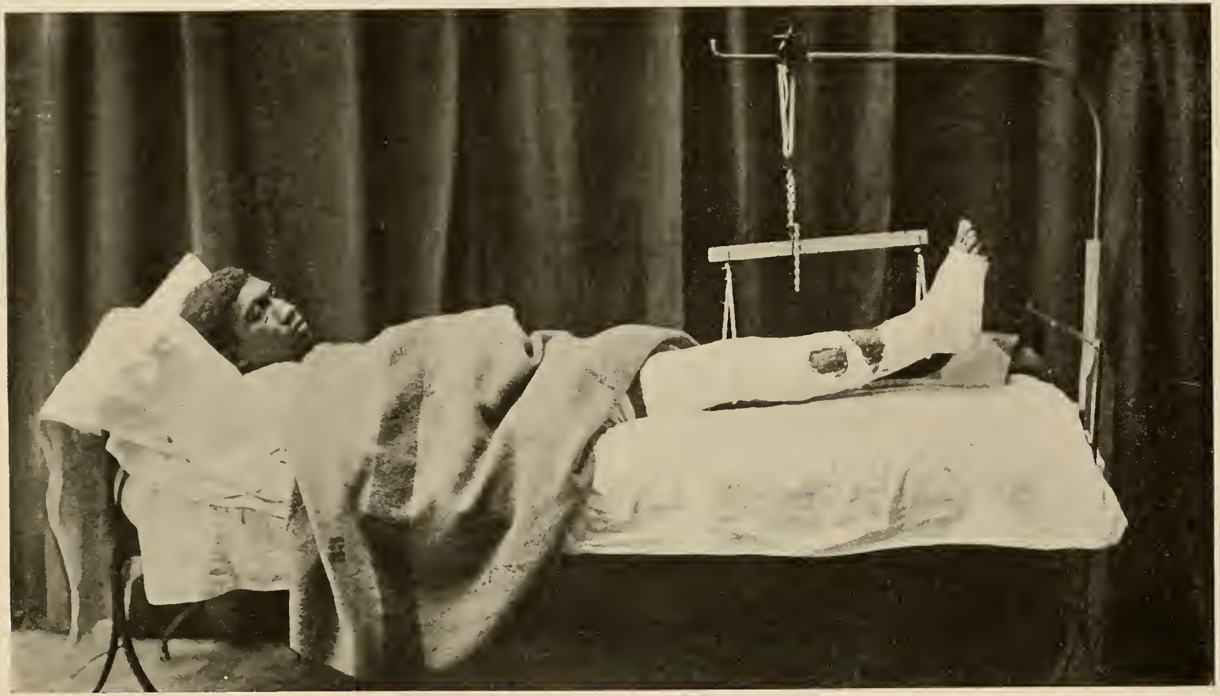

PLATE VI.

Suspension Apparatus Applied to a Compound Fracture of the Leg. The leg is in plaster-of-Paris splint to afford extension of the range of coarse motion.

PLATE VII.

Suspension Apparatus Applied to a Compound Fracture of the Leg in a Plaster-of-Paris Splint. Showing increase in range of coarse motion.

PLATE VIII.

Suspension Apparatus Applied to a Compound Fracture of the Leg, Treated in a Plaster-of-Paris Splint. Showing increase in range of coarse motion.

PLATE IX.

Suspension Apparatus Applied to a Compound Fracture of the Leg, Treated in a Plaster-of-Paris Splint. Showing increase in range of coarse motion.

horizontally about six inches and was turned vertically upward for a length of about two inches. This smaller pipe was held in place by having its received portion bent a little out of line, enough to give sufficient friction. A pulley, about two and a half inches in diameter, travelled freely upon the smaller pipe, being checked in one direction by the end of the larger gas-pipe, and in the other by the upturned end of the smaller pipe.

To the lower end of the pulley from which the screw had been removed was fastened a loop of a few inches of elastic rubber tubing. At the lower end of the tubing was a strong hook fashioned out of strong iron wire. Inasmuch as under the strain of constant use the loop of rubber tubing was apt to break, the weak point was guarded by a safety line of flexible braided wire picture cord. It was fastened to the pulley above and the hook below, sufficient slack being given to allow full play to the elastic tubing under the weight of the suspended limb. Under this arrangement, the author has known the elastic tubing to break without awakening the patient from sleep, the safety cord holding the suspension rigging intact.

Into the hook at the lower end of the loop of elastic was caught a short length of chain of plain coarse round links. This chain was for the purpose of adjusting the elevation or depression of the limb. Into one of the lower links of the chain was caught the hook connected with a square loop made of rather heavy iron wire, which loop received loosely the wooden bar from which the limb was directly sus-

pended. The bar was of hard wood. On its upper edge it was grooved transversely, near each end; the grooves were about one inch apart and of a size and depth to receive easily the wire loops of the pulleys over which ran the ropes encircling the limb in splint. On its lower edge, one side of the centre, the bar had cut into it three or four notches, about an inch apart, into which could be shifted the square iron wire loop catching into the lower part of the chain. The wooden bar spaced the pulleys carrying the suspending loops of rope which could consequently be held in predetermined position. The notches in the upper edge of the bar, at each end permitted an accurate spacing of the loops of rope and those in the lower edge, a nice balancing of the suspended limb.

The pulleys carrying the ropes suspending the limb were treated in this way: The screw of each pulley was cut off flush with the body of the pulley; in its place a square loop of wire to slide back and forth over the wooden bar was fastened to the body of the pulley, the plane of the loop, of course, coinciding with the plane of the pulley wheel; this loop was made sufficiently large so that when the pulley hung in place from the bar there would be left ample space between the upper surface of the body of the pulley and lower surface of the bar so the pulley could not only be shifted into position in different notches in the bar, but might swing freely, thereby accommodating its plane of rotation to any inclination of the rope, which, were the pulley fast to the bar, would ride off or block the wheel. The limb was suspended directly from the pulleys by

loops of small rope which rode easily in the pulley grooves. In action, the limb was comfortably suspended by the encircling loops of rope which were accurately spaced, and balanced in the best position. The elevation or depression could be regulated to a nicety by the links of the chain.

Except for special reasons, as a general principle, the limb should be lifted as little as possible from the plane upon which its healthy fellow rests. Indeed, the writer in observance of this principle has sometimes depressed the underlying portion of bed, rather than elevate the limb. When the limb is much elevated, the lower fragment tends by gravity to override the upper fragment and gives rise to the disagreeable necessity of using some sort of extension apparatus to correct the difficulty, with a consequent restriction of motion of the lower fragment. By means of the apparatus the resistance to motion in horizontal and vertical planes and to rotation upon the long axis of the limb has been lessened. By virtue of the elastic suspension from a single point, the resistance to elevation of the limb is lessened, which is sometimes, as in the delirium of the patient, of material advantage. Given the wooden upright bored to receive the iron pipe, and the wooden bar shaped to form, all the materials can be assembled in construction by the surgeon's own hands, at least that was so in the writer's experience. Frequently the author in making his rounds observed patients who were able to walk about, sitting in their chairs with the leg in splint resting in the suspension apparatus described, fastened to the chair, rather than

resting upon a pillow in an opposite chair. To inquiry, the answer was always given that it was the more comfortable choice. It will be noted, of course, that the suspension apparatus for the patient with fracture of both thighs was an adaptation of the construction in use for fractures of the leg.

In the preantiseptic days in Bellevue Hospital, when that institution was saturated with infection, it was customary in the treatment of compound fractures to cut fenestræ in the immovable plaster-of-Paris splint, for the purpose of watching and treating the wound. It generally happened that there was burrowing of pus, and the opening in the splint had to be enlarged to increase the area under observation and treatment. This led the author by rapid steps to finally discard altogether the encasing and concealing splint, obstructive of surgical procedures, and to adopt means of treatment which though opposing feeble resistance to forces tending more or less to displace the fragments, gave freest access for observation and surgical treatment. The splint had become restrictive of surgical treatment demanded by the functioning of the injured tissues.

The limb was so circumstanced that while some control was exerted over the immobility of the adjusted fragments, it was completely open to inspection and palpation and treatment of the wound complications. All absorbent dressings were discarded. *No wound-dressings* were used. The pus drained away, and was not decomposed by being held in contact with the warm limb. There was no squeezing of tissues to evacuate sinuses, indeed in tissues that

were not handled but kept in absolute physical rest the burrowing of pus was slight or did not occur. The patient was spared the pain of the usual mode of dressing. The dressing was only the substitution of a clean for a soiled support, and this was so performed as sometimes not to awaken the patient from sleep. The success following the carrying out of these principles was so great, especially with primary amputations, that the writer was slow to adopt the antiseptic measures of treatment as at first practiced.

Later experience in the then highly septic wards of Bellevue Hospital convinced the author that *antiseptic measures* of treatment could fully protect patients against sepsis. He accordingly discarded the method and apparatus which, though giving the excellent results in his hands in septic surgical practice, afforded but feeble control over the maintenance in position of the adjusted bony fragments. Strict antiseptic measures having reduced the chances of septic wound complications in compound fractures to the vanishing point, such fractures could therefore be placed in a category closely allied to simple fractures, and a consequent greater control could be exerted over the maintenance of the fragments in adjusted position, as already described in the use of tin strips in conjunction with antiseptic measures of treatment.

The illustrative instances that have been presented might be largely increased in number from the author's experience. It is thought, however, that they provide ample subject-matter for the purposes

of our induction, which has as its objective, the organization of the facts through the principles which they embody. We therefore now pass from a consideration of the concrete to a study of the abstract.

All methods of treatment of fractures of the long bones to insure their union, however diverse in characteristics, have one constant feature in common, which may therefore be regarded as the essential factor or attribute. This attribute is *maintained immobility of the fragments.* The essential nature of this attribute is further shown by the demonstrable truth of its contradictory, that disturbance of the continuous immobility of the fragments beyond a certain degree will prevent their union.

It has been pointed out that no extrinsic apparel in opposing its resistance to disturbing forces through the soft parts can completely immobilize the fragments. While, therefore, maintained absolute immobility under those conditions is unattainable, yet a degree of immobility practically sufficient to insure union, as has been amply demonstrated, can always be achieved; this attainable degree of sufficient immobility may, therefore, be termed practical immobility, in distinction from theoretical or absolute immobility.

Just what excursion of motion between the fragments, disturbance of immobility, may take place consistent with the fragments uniting, is not easy of determination; it probably varies with individual patients. In view of this, it is incumbent upon the surgeon to bestow upon his patient a sufficient factor of safety in restricting motion between the fragments, to insure their uniting.

The maintained practical immobilization of the fragments, in the realization of the essential attribute common to all methods of treatment, is accomplished by the adjustment of mechanical forces to resist mechanical forces acting to disturb their immobility. The essential attribute is a mechanical one. The measure of its value in a scheme of values is not related to the degree of attainable immobility per se, said attainable immobility in turn being related to an ideal standard of absolute immobility as a test of excellence. The measure of its value is determined through the extension of that factor, in the relation of the varying range of forces maintaining practical immobility, to the incident forces tending to disturb it. In other words the essential attribute, maintained practical immobility, is treated as a constant, the range of forces tending to disturb the immobility, as the functioning variable.

The maintenance of practical immobility of the fragments by the adjustment of mechanical forces to oppose a varying range of forces tending to disturb that immobility is proximately measured in its degree of excellence by the varying range of coarse motion of the organism, the test of excellence being shown in the degree of practical realization in approach to the ideal of largest range of coarse motion. In brief, the efficiency of the essential attribute, sustained practical immobility, being granted, the measure of its value is the varying range of coarse motion of the organism, the essential attribute being preserved, the highest value being assigned to the greatest range of coarse motion of the concerned organism. Changes

in coarse motion in their turn extend their effects to all the various fields of function.

Nor does the ideal, it may be noted, propose as its limit of excellence the restoration of the former or so-called normal field of coarse motion, which, in results, may conceivably be even surpassed.

It may be further pointed out that the term "results" is not limited in its application to a certain period of treatment, as, for example, the time of union of the fragments. Such is an arbitrary limitation in time of the application of the term. The estimation of results should be extended to include any period or all periods of treatment, even those during which union is taking place.

Results, considered as immediate, remote and multiplied effects, have an indefinite extension of application, not even being limited by, or ceasing with the life of the individual, but extending their influence to the effect on the welfare of the social organism itself. Indeed, had we an all-embracing grasp, all results, like all actions, from the smallest to the greatest, should be determined in the measurement of their value by this final of all tests. A proximate test, however, is sufficient for our inquiry. In determining the relative values of the essential attribute embodied in various methods of treatment in its extension, the degree of excellence is in the proportionate realization by a given method of treatment of the ideal of highest excellence, as shown by the increase in motion of the affected individual.

The means by which the essential attribute is made operative, in other words, methods of treatment

considered apart from the essential attribute itself (which, to repeat, is a mechanical one), and considered in reference to their inseparable accidents or characteristics, may be generalized under two heads:

First, in their local influence, affecting functioning of the injured limb.

Second, in their particular, peculiar effect upon the tissues; in other words, in their therapeutic influence. Both heads may be considered under the effect of function, extending the connotation of the term function beyond its ordinary, arbitrary, accepted signification, to include all responses of the concerned tissues, whether normal or abnormal, to the distributions of conditions to which they are exposed.

By parity of consideration with that of the essential attribute, it is evident that in the function of variable responses to varying distributions of environing conditions, the theoretical maximum of excellence must connote the largest response to distributions of environing conditions. It follows, therefore, that the degree of excellence is necessarily proportionate to the largest response, in practical realization of approach to said ideal of largest response. Under the same head may be included the variable results of the so-termed therapeutic influence. To repeat: The results following from the effects of the non-essential attributes of treatment (the inseparable accidents or characteristics), considered apart from those due to the realization of the essential attribute, are to be measured in their excellence by their degree of approach to the ideal of highest excellence, in terms of function.

In exhausting the subject-matter, both essential and non-essential attributes of treatment inclusive may be generalized in their results under the head of functional responses of the organism to the distributions of conditions to which it is exposed. The comparative value of said responses in their immediate, remote, and cumulative effects are measurable as proportionate to the largest response, in approach to the theoretical ideal of maximum response.

In the foregoing reasoning, which has been briefly presented, and might be easily elaborated, and, it is trusted, will be made clear by illustrations, the author has been engaged in laying the foundation of impersonal proof of value of any method of treatment, to displace the bare empirical assertion of values resting on personal authority or consensus of opinion.

The voicings of personal authority may contradict each other, or when made by the same individual may vary at different times. The weight of the consensus of opinion may sustain one conclusion to-day, its contradictory to-morrow.

Impersonal truth alone is authoritative. By truth is meant that peculiar harmony of relations revealed in the upbuilding of what Prof. Karl Pearson has happily termed "the constructive field of the mind." Said upbuilding is the constructive harmonizing of continuous principles, abstractedly derived from the complex, fluid, discontinuous, ever-varying phenomena of the external world. Such organization of phenomena through the harmonizing of their embodied principles is, as the author conceives it, the final objective of all scientific endeavor.

In the region of empiricism, the social organism guided only by the weight of changing personal authority or the consensus of opinion, gropes its uncertain way; in the realm of scientific exactitude, guided by immutable principles, it confidently pursues a direct and certain course, and by proper instrumentalities at its command, insures the betterment of its constituent members.

While on the one hand the surgeon engages in his individual work for the welfare of his patient, on the other he should, through principles, instruct and equip the social organism in the knowledge of the prevention of the diseases and injuries he treats, always, therefore, in acts of self-abnegation being engaged in contracting the immediate field of his activity, as it were, cutting the ground from beneath his own feet.

It should ever be borne in mind when the asserted superiority of any method of treatment is challenged, that the defendant, to prove his assertion, should, avoiding all question of personal authority or consensus of opinion, display the premises and the reasoning therefrom, upon which his conclusion depends.

So far as relates to separable accidents, the mere proof that they are separable accidents and are avoidable, is sufficient to expose their entire lack of force in the argument. For example, the writer well remembers an occasion when an immovable splint was removed from a patient with a simple fracture of the shaft of the femur. The fragments of bone were united with no shortening or other deformity, indeed with a perfect result. However, the point of a pin

in the blanket protective covering had caused a very small phlegmon upon the abdomen. This had caused so little discomfort that the patient had made no complaint and the pustule was only known when the splint was removed. Yet, a distinguished surgeon, an authority on fractures, who was present, made careful note of the little mishap as furnishing, to his mind, an argument against the use of the plaster-of-Paris splint. The point of the pin might have been turned outward, or the pin might have been removed altogether. It was by no means a necessary element in the construction of the splint. The irritation caused by it was perfectly avoidable; it was a separable accident and, of course, had no logical force in an argument against the use of the apparel.

When the writer first entered upon his service as a member of the House Staff of Bellevue Hospital, the following incident occurred which made a deep and lasting impression. A woman with simple fracture of both bones of the leg in the middle third of the leg was admitted into the Hospital soon after the occurrence of the injury, and was seen by the Visiting Surgeon, one of the greatest authorities on fractures. He directed that the fractured leg should be treated with leather side-splints, which was at once done. At his visit next day, the patient said that she could not sit up in bed without feeling the bones grate upon each other. The Visiting Surgeon criticised the application of the splints and reapplied them himself, and also directed that the limb be suspended by loops of bandage dependent from a simple cradle placed over it. The next day the patient told the Visiting

Surgeon the same story, that she could not sit up without feeling the fragments grate upon each other. He then directed the House Surgeon to apply an immovable plaster-of-Paris splint. The next day, the Visiting Surgeon found the patient dressed and sitting in a chair, beside the bed, the fractured limb resting upon a chair opposite. She told the Visiting Surgeon that she had sat up in bed, was dressed with assistance, and had otherwise moved about, *without feeling any grating of the bones.*

In strict analysis, what had happened to the patient? As she was walking across the street, she was knocked down by a passing wagon and her leg broken. She was immediately removed by ambulance to the Hospital. By the fracture, her field of coarse motion, specialized in locomotion, had suddenly been contracted to a very small one. With her leg in a fracture-box resting upon the bed, she could not sit up without disturbing the immobility of the fragments, thereby destroying the essential attribute of treatment necessary to their uniting. The support of the limb, practically in only one plane, prevented any but the smallest range of coarse motion. Encased in movable side-splints, she could move in a very small range without disturbing the fragments. There had been adapted a resistance to a small range of disturbing forces, the fragments being meanwhile held immovable. In the immovable plaster-of-Paris splint, resistance was adapted to overcome a considerable range of disturbing forces, that otherwise would destroy the requisite immobility of the relation of the fragments. This was shown by the greatly

enlarged field of coarse motion she enjoyed, without interfering with the practical immobility of the fragments in adjusted relation, and their consequent union.

In the three separate distributions of conditions constituting the three varieties of treatment, the essential attribute of maintained practical immobility of the fragments had been preserved with three different results as marked by three different degrees of extension in functioning of the essential factor or attribute. This extension was expressed by three different degrees of coarse motion, the essential factor or attribute being preserved, as shown:—

First, by a very limited range of coarse motion,

Second, by an increase in the range of coarse motion, and

Third, by a still greater range of coarse motion.

These three degrees of enlargement of coarse motion derived their value in excellence measurable by their degree of approach to a practical realization of the ideal of greatest range of coarse motion. Assigning highest excellence to the greatest enlargement of the field of coarse motion in practical realization of said ideal, then the second distribution of conditions produced a result of higher value than the first distribution and the third distribution produced a result of higher value than the other two. In the foregoing illustration of comparative values, consideration has been restricted to an extension of the essential factor or attribute, as a functioning variable.

Limiting our consideration to the essential factor or attribute, the term plaster-of-Paris splint is a

highly ambiguous one. It connotes a great variety or range of resistances, as expressed in extension by degrees of coarse motion of the concerned organism. For example: a plaster-of-Paris splint may be so loosely applied that it affords no greater resistance to displacing forces than the simple fracture-box as shown by the extremely limited range of coarse motion without disturbance of the fragments. At the other extreme it may be so efficiently applied that it gives a great resistance to otherwise disturbing forces, as shown by a great range of coarse motion on the part of the concerned organism, without disturbance of the practical immobility of the fragments. It may consequently be so applied as to develop all degrees of resistance between the extremes, its inseparable accidents or characteristics remaining the same.

Then again, the enclosed limb may so diminish in bulk from recession of swelling as to greatly change the resistance afforded by the splint. The author has seen a well-applied splint upon a limb considerably swollen allow the fragments to fall out of adjusted position in a short time on account of subsidence of swelling, and the splint itself afford no more resistance to disturbing forces than a roofed-in fracture-box.

In any argument concerning the value of a plaster-of-Paris splint applied in a given instance, the particular resistance to incident forces which it connotes should be exactly specified; better, indeed, the specific connotation should be used rather than the term itself, which is so variable in its connotation.

In compound fractures, or simple fractures with

much injury to the soft parts, forbidding that degree of compression by the splint to afford resistance to a large range of incident forces tending to disturb the practical immobility of the adjusted fragments, in other words limiting the extension of the essential attribute or factor, the incident forces are so disposed by suspension apparatus as to extend the functioning of the essential factor, thereby increasing the range of coarse motion of the concerned organism.

The more clearly to understand the use of suspension apparatus in its relation to the extension of the essential factor, it will be instructive to trace in the evolution of its functioning the forms of apparatus that have been described, as formerly used in Bellevue Hospital.

The simplest form of suspension apparatus is that in which the broken leg is suspended by loops of bandage dependent from a simple cradle placed over the limb. This apparatus is a distribution of conditions modifying the incident forces otherwise disturbing the essential attribute (maintained practical immobility) in such a manner as to extend the relations of the attribute, as shown by the enlargement of the field of coarse motion of the afflicted organism, meanwhile preserving the essential factor in its efficient operation.

Dr. Van Wagenen's excellent appliance so modified the distribution of disturbing forces as to extend the functioning of the essential factor or attribute as shown by the greater enlargement of the field of coarse motion of the concerned organism, the operation of the essential factor being preserved.

The apparatus contrived by the writer still further modifying the distribution of disturbing forces, in such wise as to extend the functioning of the essential factor, is shown by a larger range in the field of coarse motion on the part of the organism.

In recapitulation, Appliance No. 1 modified the incident forces acting upon the lower fragment principally in a single plane so that the patient could move the broken limb in a single plane without the disturbance of maintained practical immobility of the fragments, a resulting slight enlargement of the patient's field of coarse motion.

Appliance No. 2 (Van Wagenen's) modified incident forces operating in more planes and especially those forces operating upon the lower fragment to prevent rotation of the limb on its longitudinal axis, without disturbance of the fragments in adjusted relation, a resulting decided increase in the patient's field of coarse motion.

Appliance No. 3 (the writer's) modified the distribution of incident forces operating in more planes and upon more axes: resulting in still greater increase in the patient's field of coarse motion without disturbance of the maintained immobility of the fragments.

The three appliances respectively, were distributions of environing conditions affecting incident forces tending to disturb the extension of the essential attribute common to all three methods of treatment. They were extensions of the functioning of that factor as shown by the increasing degrees of enlargement of the field of coarse motion of the pa-

tient, the action of the essential factor being always preserved.

As a general principle, unless special reasons contradict, the suspended limb should be elevated as little as possible above the plane upon which its healthy fellow rests. A notable exception is suspension in vertical traction of a simple fracture of the femur in a child, which strictly analyzed gives the greatest range of coarse motion of the individual, the essential attribute of practical immobility of the fragments being preserved.

The elastic suspension acting from a single point was advantageous in modifying the resistance to elevating the limb, which was of importance in extending the range of coarse motion in certain critical conditions of the patient, like delirium.

Having considered diverse categories of distributions of conditions in the influence upon the extension of the essential factor or attribute as expressed by results interpreted in terms of degrees of coarse motion of the concerned organism, we now compare the various categories of distributions of conditions in reference to their *inseparable accidents or characteristics* in their influence upon the organism, apart from the influence upon the essential factor. This is expressed through a common medium of proof of their value. We have divided this consideration under two heads, one the modification of the concerned organism expressed in terms of function, and two, the special or therapeutic influence of such distributions of conditions as exerted by extrinsic apparel.

One: It is to be understood in our consideration that the signification of function is not arbitrarily limited to modification of the responses usually expressed by normal or healthy tissue, but is extended to include *all* responses of the concerned tissues. This comparison is perhaps best made by a study of the categories of distributions of conditions themselves, taking for our study as illustrative examples three different methods of treatment of a given fracture of the leg, first, in a fracture-box; second, by movable side-splints, and third, by immovable plaster-of-Paris splint.

So far as relates to ordinary phases of functioning, the first or simple support in the fracture-box (considered apart from the essential factor) imposes the least limitation upon ordinary function. Such distribution also imposes the least restraint upon surgical relations of the injury. In the latter respect the injury is open to inspection, palpation and extended surgical treatment.

In the second category, that of movable side-splints, there is greater restraint upon what is termed normal functioning, and there is also greater restraint upon the functioning of the limb in reference to surgical relations. The tissues are not so readily open to inspection, palpation, or surgical treatment.

In the third category, that of the immovable plaster-of-Paris splint, there is a still greater restriction than in the other two categories, upon the normal functioning of the limb. The tissues are withdrawn from inspection, palpation, and are not open to a range of surgical procedures.

In recapitulation, the first category of conditions imposes the least restraint upon, or limitation to functioning responses, including surgical relations. The second imposes a greater limitation of responses, and the third and greatest of all limitations of responses, limiting the surgical relations to a near approach to the vanishing point.

In therapeutic influence, which is really a phase of functioning, the first category of conditions imposes no special therapeutic influence upon the tissues beyond physical rest; the second category imposes the deleterious influence of more or less confinement and withdrawal from the light; the third category accentuates the effects of confinement and absence from light and air, to which may possibly be added a special influence from the material of the permanent apparel itself. Broadly expressed, the therapeutic influence of the environing distribution of conditions in the third instance is at the maximum; in the second category it is in moderate degree; and in the first category it is near the vanishing point.

The therapeutic influence of the plaster-of-Paris splint is of such great importance as to demand extended consideration. It is not to be overlooked that in the early stages of its application the plaster-of-Paris apparel exerts a beneficent influence upon the included tissues mainly by inducing rest and quieting muscular action. The injurious effect of the splint is cumulative, increasing with the duration of its application. Great changes are induced in the skin as shown by its anæmia and readiness to become œdematous. Nor is the deleterious influence of the splint

limited to the skin, but extends to all soft tissues and even to the bones themselves. The changes in the soft parts are not only evident but also invisible, and are strikingly illustrated by their behaviour under infection.

In preantiseptic days when Bellevue Hospital was saturated with infection, great care was exercised in the removal of splints lest the skin be scratched and infected with erysipelas. Nevertheless, erysipelatous infection frequently occurred. The destruction wrought by such infection upon the tissues that had been covered by the splint was wide-spread and in some instances accompanied by unusually large and deep sloughs of subcutaneous tissues. In some instances the erysipelatous inflammation would rapidly sweep over the limb affecting the portion formerly encased in the splint, and then stop abruptly in a sharp circular line, bounding the upper limit of the splint.

The deleterious therapeutic influence of the splint was in addition also otherwise shown in striking manner as affecting the union of the bony fragments. In one illustrative instance, a patient with a compound fracture of both bones of the leg, had been treated in a plaster-of-Paris splint without suspension of the limb, for more than six weeks. Suppurating sinuses connecting with the wound had formed, as was frequently the case in such injuries. The wound was not yet healed when the splint was removed. There was no union of the bones whatever, and the limb taken from the splint was placed in a fracture-box. The exposed limb, enjoying its larger functional

range, was then frequently sponged, and stroked with the hand, *the immobility of the fragments meanwhile not being disturbed.* To the astonishment of the House Staff, *in four days the leg began to stiffen and* healing progressed rapidly to a complete union of the fragments.

A patient with a simple fracture of both bones of the leg at the middle of the leg, was in the middle period of pregnancy. After the limb had been encased in a well-fitting plaster-of-Paris splint for six weeks she came under the writer's care. There was no union of the fracture whatever. There was free angular motion at the site of fracture. The limb was forcibly douched with hot and cold water alternately, always leaving off with the cold douche. The limb was gently massaged three times daily, and the patient was encouraged to exercise the muscles of the affected limb under the stimulus of the will, *the fragments during all procedures being held immobile.* The splint, which had been cut down in the anterior median line was used as a *movable* apparel, and worn only when the limb was exposed to injury, and consequently was very seldom upon the limb during the day-time. In a very few days the fragments began to unite; the bones stiffened and union progressed uninterruptedly to solidity.

In other patients, where there had been long delayed union from prolonged confinement in immovable plaster-of-Paris splints, with apparently hopeless prospect of union, indeed, in two cases that had been condemned to operation, the same practice of revivification narrated above (persistent invitations

to increase of function) was completely successful in steadily effecting complete and solid union of the fragments.

The measures were strikingly successful in one remarkable case in private practice, of delayed union of fracture of the humerus of several weeks' duration which seemed hopeless of union and in which the open operation upon the fragment had been advised as the only presumed remaining resource.

In the author's own practice, which was very extensive, he rarely had an instance of delayed union and, according to his recollection, never an instance of non-union in any variety of fracture.

In brief, the plaster-of-Paris splint, in its mechanical, essential attribute embodies the greatest mechanical resistance to forces tending to disturb the continuous practical immobility of the fragments in their adjusted relation, as shown by the extension of that attribute as a functioning variable, its superior excellence being shown by the large range of coarse motion of the organism, the practical immobility of the adjusted fragments being maintained. On the other hand, in its non-essential, constant attribute, that is, in its inseparable accidents or characteristics, so far as its therapeutic influence is concerned, it is the most deleterious of all extrinsic appliances that have been reviewed. It is very restrictive of function of the included tissue, giving to the term function its broadest signification.

This restriction for a limited time of early treatment is beneficial by quieting the muscles and thereby indirectly assisting in the maintenance of immobility

of the fragments. The induced œdema also assists in the tight packing of the splint thereby promoting its mechanical efficiency. In its continued application, however, by its restriction of the surgical relations of the limb (its surgical functioning) by preventing inspection and palpation, it greatly diminishes the range of choice of beneficial surgical measures otherwise included in the categories of conditions constituting the treatment of the injury. The distinctly bad therapeutic influence of the splint upon all included tissues, said injurious influence being cumulative and proportioned to the duration of the application of the splint is in strong contrast with the distinctly beneficial influence of the contradictory in categories of conditions, which enlarge the functioning of the tissues, using the term functioning in its widest signification.

It follows therefore that in the distributions of conditions through the use of extrinsic apparel, to evoke the largest responses from the organism the plaster-of-Paris splint should be applied during the earlier stages of treatment when the adjusted fragments may be the more easily distributed in their immobility and when the tissues are healthy. In the latter stages of treatment when the fragments may be the more easily held immobile, the plaster-of-Paris splint should be discarded and for it should be substituted some form of movable splint which, while continuing equally well the operation of the essential factor of maintained practical immobility at the same time allows a larger response to be evoked from the functioning tissues.

In the author's treatment of *compound fractures*

in preantiseptic days in an infected hospital, the plaster-of-Paris splint was gradually discarded by him. Instead of the splint there were substituted appliances which permitted an enlarged range of surgical treatment. To reach and treat complications of the septic wound, the window in the splint was at first enlarged, then further enlarged, and finally the obstructing envelope of the splint was discarded altogether. To give extension to the essential factor under such circumstances, special appliances were devised, which in the author's hands yielded satisfactory results. Some control was exerted over the immobility of adjusted fragments as shown by some, though limited, range of coarse motion. The injurious therapeutic influence of the splint was eliminated and an extended surgical functioning range of the tissues was secured.

Some of the appliances used were somewhat complex in construction but quite simple and effective in action. In their turn, efficient antiseptic measures totally changed the distribution of conditions in wound treatment, and allowed the substitution for the complicated treatment of compound fractures of a category of conditions closely allied to that used in the treatment of simple fractures. This of course resulted in its turn in a further extension of the operation of the essential factor as marked by an increase in the range of coarse motion, the maintained practical immobility of the adjusted fragments being undisturbed by incident mechanical forces; at the same time the influence of the wound as a complicating element was reduced to the vanishing point.

In the instance of simple fracture of both femora at the middle of their shafts, after the immovable splints had been applied, the patient was anchored in one position in bed from which he could not move except when helped. He very soon became dispirited and lost strength. The suspension appliance shown in the photograph was at once devised. By its means the patient's range of coarse motion was immediately enlarged, with a consequent improvement in morale and gain in strength. His increase in weight kept the splint a snug fit and consequently an efficient mechanical resistance to incident mechanical forces. The splint was not once changed till it was finally removed, when the fractures were found united without deformity and of equal length. Such a result is indeed even apparent from an inspection of the photograph showing the limbs still encased in the splints.

To generalize:—We have found that the measurement of the essential attribute (maintained immobility), under extension from a zero toward a maximum, comprehends variation in coarse motion of the concerned organism. This variation extends from a lessened degree caused by injury, through a range of increased motion toward a maximum, which maximum is a proximate measuring test of the realization of the criterion of excellence. These variations in coarse motion, though classified as variations in special functionings of the organism, may be generalized as responses of given states of the organism to given distributions of conditions constituting the phases of treatment of the injuries. Likewise, the variations of

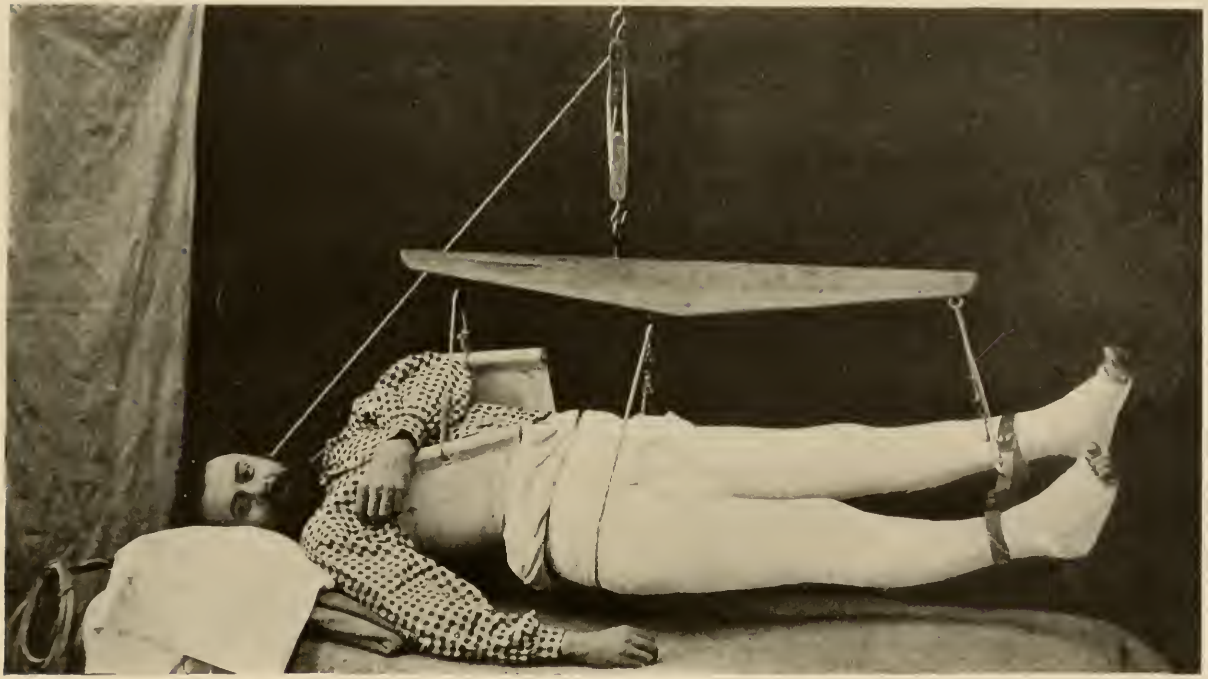

PLATE X.

Suspension Apparatus Applied to Fracture of Both Femora at Middle of Shafts. Showing increase of range of coarse motion.

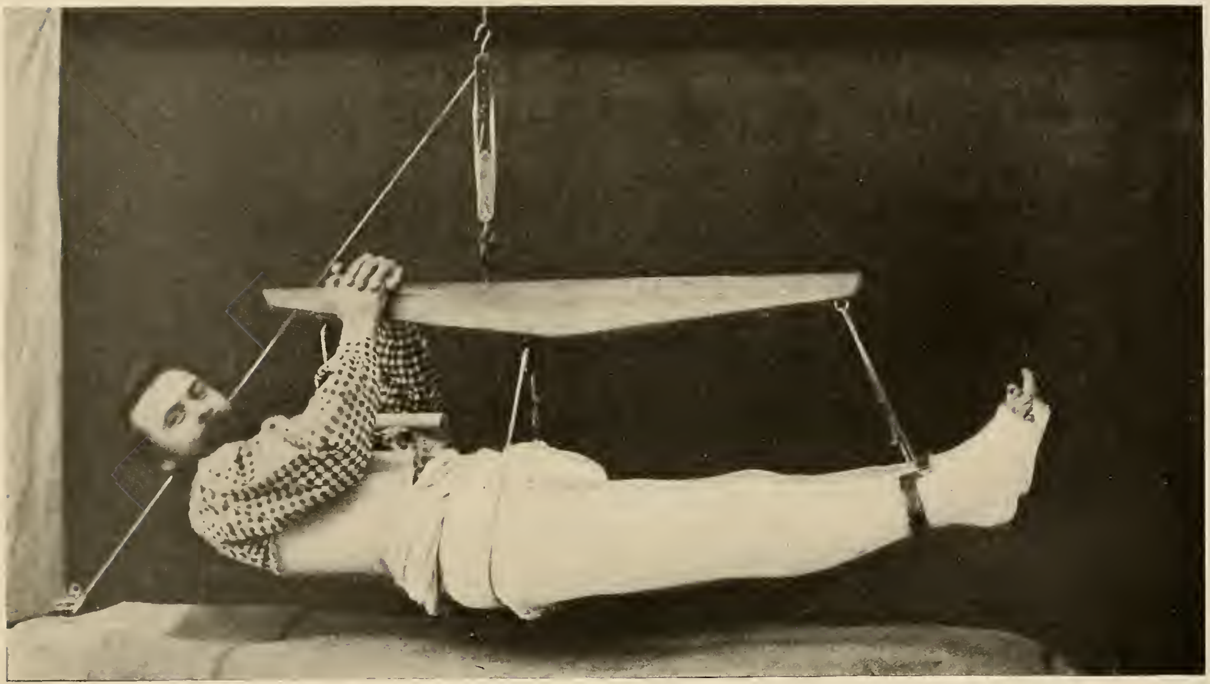

PLATE XI.

Fracture of Both Femora at Middle of Shafts in Suspension Apparatus. Showing increase of range of coarse motion.

the characteristics of treatment (the inseparable accidents) extend through a range from a zero to a largest functioning, which functioning, however specialized in classfication, may be constituted and made measurable as responses of the given states of the organism to given distributions of conditions, all being in relation to, and measurable by, the criterion of highest excellence constituted by the largest number of responses.

It is thus found that both the essential attribute, and the inseparable accidents (characteristics) of all methods of treatment (exhausting the subject-matter under study) may be generalized under the common head of responses of the concerned organism to the distributions of conditions to which it is exposed by the proceedings of surgical art.

The measure of quality is necessarily quantitative and in the last analysis is resolvable into and expressible in terms of number.

It is gratifying to find that the conclusion, independently reached through our induction, harmonizes with the Spencerian definition of Life.

Spencer, in his "First Principles," says: "Divesting the conception of all superfluities and reducing it to its most abstract shape, we see that Life is definable as the continuous adjustment of internal relations to external relations. And when we so define it we discover that the physical and the psychical life are equally comprehended by the definition."

Such continuous adjustments are expressed in responses of the organism and may be quantitatively measured in terms of number. The individual life

as a variable, measurable in terms of number, obviously extends in variation from a zero, or vanishing point, to a maximum number of responses.

The categories of distributions of conditions constituting the treatment of injuries evoke a variable number of responses, which variations in number extend from a zero to a maximum. In our ideal scheme of values the criterion of highest excellence is constituted by the maximum number of responses.

Practically, the surgeon is always engaged in determining by observation, and defining the categories of conditions embraced in varying states of the organism. His treatment consists in supplying to the defined categories of conditions embraced in given states of injury given categories of distributions of conditions. The categories of responses evoked from the organism, constituting the results of treatment, are measurable by the connoted number of responses. Their value is estimated in relation to a maximum number of responses, constituting the practical realization of approach to the maximum number of responses constituting the ideal of supreme excellence. It follows therefore in comparison of the value of methods judged by their results, that that method of treatment is better and to be preferred over another, which in its result evokes the larger number of responses measured in the presence of the criterion of highest value, the maximum number of responses.

The results of treatment in connoted responses, called forth from the concerned organism by the category of distribution of conditions to which it is exposed, in their effects are immediate, cumulative and

remote, extending their influence to the social organism.

It will be observed that the criterion of value though most general in expression includes classified functions of the organism, modes of relation.

In the complex and variable subject-matter embraced in the province of surgery, the formation and definition of distinct groups or categories is an important task.

These categories embrace states of the organism, distributions of conditions constituting surgical treatment of said states, and categories of responses constituting the given results of treatment.

Refinements of observation, changes in the organism itself, the invention of new distributions of conditions in treatment, lead to the creation of new categories and their consequent definition.

The multiplication of instances in categories already constituted and defined, as an end in itself, is, scientifically viewed, an unnecessary loading of the record in confirmation of that which has already been established.

The writer knew a surgeon who died unhappy because he had performed a certain operation only ninety-nine times, failing to obtain and operate his hundredth patient. And yet, all his operations added nothing new to categories already known and defined, extended no new embodied principle and after all, only, as is too often the case, burdened the record to no commensurate useful end. Indeed, the very operation which he performed with so much skill and pride was very properly superseded before his death by another operation attaining the same object

equally well, and with the advantage of expressing much greater scope.

To sum up: A given fracture is a given definable category of conditions of the state of the injured organism. A given treatment of the fracture is a given definable category of distribution of conditions to which the given injury is exposed. The result of treatment is a given definable category of responses evoked from the injured organism consequent upon its exposure to the given category of distribution of conditions constituting the treatment. *The criterion or measure of value of the results of treatment is the largest number of evoked responses, in practical realization of approach to the conceived ideal of maximum number of responses.*

There may be difficulty in determining and defining the given categories but *the method of determining values remains always the same and immutable,* unaffected by, and independent of, the dicta of personal authorities or the consensus of opinion.

Reduced to syllogistic form, that method of treatment when compared with another is better and to be preferred, that evokes the larger number of connoted responses from the category of distribution of conditions to which the injury is exposed, in practical realization of approach to the ideal of supreme excellence, which is that of the largest number of responses. A certain method of treatment in its results shows a larger number of responses in practical realization of approach to the ideal of maximum number of responses when compared with others, and is therefore the better method and should, in obedience to ethical requirements, be preferably adopted.

SEPTIC SATURATION OF BELLEVUE HOSPITAL IN THE SEVENTIES. BATTLE AGAINST SEPSIS

The saturation of Bellevue Hospital, in the seventies, with erysipelas infection is well illustrated by the following example: On one occasion in entering upon his term of service, the writer found in his ward a patient suffering from a discharging sinus of the brain caused by a pistol-shot wound inflicted six weeks before (see Plate XX, Fig. A). The sinus having definite walls was easily probed and the ball touched near the centre of the brain. Small hair-pin like retractors were made of wire. The brain was slightly incised and the imbedded ball was plainly seen in its position. It was seized with proper forceps, but was felt to resist traction upon it very much as a button sewn upon a coat. The ball was partly encysted. It was wiped clean and a small flake of lead was picked from it with forceps. Recognizing that an attempt to remove the ball was fraught with great danger and being under the obligation not to perform any dangerous operation upon the patient, manipulation was restricted to wiping the sinus clean with the object of disinfecting and healing it. The sinus healed kindly till only a spot of granulations about the size of the thumb-nail remained.

At a visit at this time to inspect the wound, the corner of the covering antiseptic dressing was lifted just enough to give a view of the wound. The gauze stuck to the granulations and in lifting it a bleeding of two or three drops was caused. Just at that moment a near-by door leading into the corridor and stairway was opened permitting a strong inrush of cold air. The door was instantly shut. This happened at the very instant the dressing was lifted and sight caught of the wound. At the same moment the gauze which had not been removed clear from the head, but turned slightly back, was at once turned down and bandaged again in position. The whole incident occupied but a few seconds. The patient was shortly afterward seized with a chill and affected with erysipelas spreading from the wound. His head swelled enormously, closing his eyes, etc. Fortunately the erysipelas ran a favorable course without suppuration. The patient recovered and was discharged cured.

It was clear that the broken small spot of granulations was infected during the brief exposure at the time the blast of air came in through the opened door. The writer having no case of erysipelas in his wards was interested in tracing the source of infection. He found the ward immediately below the one occupied by his patient was being dismantled for fumigation, on account of an outbreak of erysipelas which had affected three or four patients, spreading from bed to bed, adjoining. It was perfectly clear, therefore, that the infection originating in the ward one flight of stairs below, had passed into the corridor, lurked

upon the stairs, and entered the writer's ward upon the blast of air when the door was opened.

The septic condition of the wards was so generally known that it had become a matter of public notoriety. Patients dreaded to be carried into Bellevue Hospital and with good reason. Their outlook for recovery from serious wounds would have been far better had they been operated upon in the open street where they had been injured, and afterward cared for there by the charity of the passers-by. The Hospital, although provided with a staff of brilliant surgeons, was a centre of danger. It was the only large hospital that served the needs of a great and growing city and was crowded with patients suffering from open wounds. The writer never saw a healthy open wound for the year and a half while he was interne of Bellevue Hospital. The simplest as well as the most serious wounds alike became infected, and patients in greatest proportion of instances died from septicæmia and pyæmia. The complications due to sepsis were a great discouragement to operative procedures and as a consequence attention and skill were concentrated and lavished upon bloodless operations. The peculiarities of the practice of septic surgery required great skill and trained judgment and stress was very properly laid upon the education of the hands, or as expressed in established phrase, the "*tactus eruditus.*"

The great prevalence of sepsis early drew the writer's attention to the invention of preventive measures against the dread disease. Thinking that perhaps the poor nourishment provided by the Hospital

was a factor of some importance, he organized a private source of food supply for certain patients suffering from the most serious open wounds and primary amputations. The better feeding had no perceptible influence in diminishing the occurrence of septicæmia. He next directed his attention to the overcrowded condition of the wards with open wounds. Acting upon this line of thought, he cleared one of the largest wards of all patients having any open wound whatsoever. In such a ward, he placed a patient with a primary amputation, the operation, of course, having been most skilfully performed by an exceptionally experienced surgeon. This patient was unremittingly attended night and day by the best nurses, and provided with the best nourishment. In spite of all, he developed septicæmia and followed the fatal course of his predecessors.

About this time, the writer was selected to take charge of and reorganize "the Park Reception Hospital." This was the first reception hospital that was established in the city. It cared for all emergency patients in the lower part of the City, below Canal Street, and had been in operation between two and three years. Although a great many patients were transferred from the Reception Hospital to Bellevue Hospital, yet its wards were crowded with patients suffering from serious injuries.

The large number of deaths from septicæmia in Bellevue Hospital was of such common knowledge that the newspapers mooted the advisability of tearing down that great Central Hospital and building

in its stead, at different places about the City, numerous small hospitals.

A committee of the Medical Board of Bellevue Hospital investigating the matter found that a greater proportion of patients died from septicæmia and pyæmia in the small Reception Hospital than in Bellevue Hospital. Patients were dying in "The Park Reception Hospital" from those complications when the writer took charge. Experience in Bellevue Hospital had taught the writer that skilful performance of operations, combined with nourishment with the best food, the most careful nursing, together with reducing the number of open wounds in a ward to a single wound, all, had no perceptible influence in preventing the disease. One factor remained and that was the influence of the environing walls of the hospital wards themselves. In Bellevue Hospital the floors had been washed and the bedding changed frequently enough, but the walls of the wards had not been washed within recollection. The writer reasoned that the infected walls constituted the efficient causative factor of which he was in search. Accordingly, in assuming control of the Park Hospital in which, as stated, patients at the time were dying from infection, he directed his attention to the *walls* of the wards, in addition to other measures of cleanliness. The hospital building was an old one, and there were many cracks in the walls. Under the writer's own supervision, the walls were thoroughly washed with soap and water, the ceilings were whitewashed and all cracks were injected with a 5 per cent. watery solution of carbolic acid. And this was frequently

and thoroughly done under supervision, as a matter of routine.

The Hospital after that procedure was more crowded with serious open wounds than ever before, and yet, *after the first two weeks, when the system had been thoroughly brought into efficient operation, no case of septicæmia or pyæmia ever occurred during the writer's charge of the hospital which was for a period of nearly two years.* As a gratifying consequence the death-rate of the Hospital was reduced 30 per cent., although retaining many operative cases of a class that had hitherto been transferred to Bellevue Hospital; all of which facts were made a matter of official record.

On account of this successful administration of the Park Hospital, especially in the matter of suppressing the occurrence of septicæmia and pyæmia, the writer was appointed to take charge, in addition, of the Ninety-ninth Street Reception Hospital. This latter Hospital cared for emergency patients in the upper part of the City, above Fifty-ninth Street. It was six miles distant from the Park Hospital, situated in a newer and fast growing part of the City where, at the time, many public improvements were in progress. The record of the Ninety-ninth Street Hospital when the writer assumed sole medical and administrative charge, was similarly bad as regards infection as was formerly the case in the Park Hospital. From his experience in the Park Hospital he anticipated no doubt that the same measures that had been so conspicuously successful there would be equally happy in their results when vigorously en-

forced in the Ninety-ninth Street Hospital. In this, however, he was disappointed. It is true that the occurrence of septicæmia was reduced in frequency, nevertheless, it continued to occur, and the writer recognized that his measures of elimination of that infection, though strictly carried out, were only partially successful.

While puzzling to discover the missing contributive factor causing failure of his efforts, one day as he was turning the leaves of the record-book of the very large Out-Patient Service connected with the Hospital, he was struck with the great number of patients that applied and were treated for some form of malarial poisoning. Upon investigation he found that at times a large number of workmen engaged in digging the streets in the vicinity for the laying of the great water-mains, were incapacitated and laid off from work on account of malarial poisoning. Further, every member of the House Staff living in the Hospital had been at times affected during his residence, and frequently members of the Staff were incapacitated for duty on that account. He also noticed that otherwise healthy patients, admitted to the Hospital for injuries other than open wounds, became affected with malarial poisoning while staying in the wards. Added to this, he was called upon to visit a patient living in a shack next to the Hospital whom he found dying, distinctly from malarial poisoning.

The conclusion was irresistibly forced upon the writer that the Hospital was situated in a zone of intense malarial infection, and he reasoned that the

depression caused by that poison was the missing overlooked factor contributive to the causation of septicæmia and pyæmia which was not present in the Park Hospital. Accordingly, he gave orders that every patient admitted into the Hospital suffering from any open wound should immediately be brought under the influence of quinine and that a mild degree of cinchonism should be maintained during the whole course of his wound treatment. This measure, combined with those previously instituted, proved sufficient to control, by prevention, the further occurrence of septicæmia and pyæmia. *Not another instance of the disease occurred thereafter, during the writer's continued charge of the Hospital, for more than a year.*

The battle fought by the writer for the prevention of septicæmia and pyæmia, which has been described somewhat in detail, concerned the environment of the patient, conditions remote from the wound. It related to what may be termed the first line of defense of the wound.

In Bellevue Hospital, in preantiseptic days, for various reasons, interesting in themselves, but which in adequate consideration would extend this note too far, very little attention was paid to this first line of defense. The members of the Visiting Staff in immediate authority over the wards were constantly changing service and consequently there was no administrative authority alive to its importance, continuously caring for this defense. In the progress of years great attention has been given to this first line of defense by improved hospital construction

and, equally important, in hospital organization and management. As a consequence the Hospital which was formerly a centre of infection and danger has become a refuge of safety in its model construction and intelligent sanitation. The first line of defense concerns the care of environing conditions remote from the wound. The second line of defense concerns the proximate distribution of conditions of the wound itself.

It is greatly to be desired that "antiseptic measures" comprehended in the second line of defense should be standardized.

How often has the writer seen a surgeon employ "antiseptic measures" which would have proven sadly defective but for the perfection of the first line of defense. Such a surgeon would have resented the imputation that the complex conditions connoted by his "antiseptic measures" were in any feature defective. Much might be written in amplification of this point which is left to the reflection of the thoughtful reader.

Broadly considered, the clinical experiences of the writer with septicæmia and pyæmia on a considerable scale in Bellevue, Park, and Ninety-ninth Street Hospitals, seem to justify certain interesting deductions.

In Bellevue Hospital in preantiseptic days the intensity of the incident cause of sepsis was fatal in a large class of recent wounds.

In the Park Reception Hospital, equally infected as Bellevue Hospital, the surgical and administrative measures narrated, directed against the incident

cause, so modified that variable as to eliminate the septic wound complications.

In the Ninety-ninth Street Reception Hospital, similarly infected, the same measures directed against the incident cause that were so strikingly successful in the Park Hospital were at first only partially successful. When, however, with those only partially successful measures were combined other measures combating another incident cause (malarial poisoning) the results were as good as those obtained in the Park Hospital.

It is highly improbable that the measures taken against sepsis were operative to the extent of totally excluding the incident cause, that they reduced the number of germs to a zero. Nevertheless, the variable incident cause was modified to that degree as to be harmless.

The incident cause of sepsis was a variable; the incident cause in combination with that of sepsis (malarial poisoning) was also a variable.

The modifiable malarial influence was practically eliminated or reduced to harmlessness by means of quinine, thus placing the patients in the Ninety-ninth Street Hospital in practically the same relation to sepsis as those in the Park Hospital, insuring a like consequent favorable result.

It cannot be held that quinine had a controlling specific influence over the septic cause, for it should be remarked that quinine had been tried in Bellevue Hospital for that purpose, even by the writer, and although enormous doses of the medicine had been given, it had only shown a temporary influence over

the temperatures of the patients and no apparent influence over the fatal course of sepsis.

It is also interesting to note (see the *N. Y. Medical Record,* June 7, 1890) that in the presence of the most virulent intensity of the septic cause the writer under strict antiseptic precautions performed a number of operations of suturing simple fractures of the patella by the open method in all stages and conditions of the injury, without the formation of pus or the occurrence of any septic complications whatsoever; and that this was done and the results achieved in the same wards where compound fractures of the patella, before the introduction of antiseptic treatment, were otherwise so generally fatal that the writer regarded a prompt primary amputation at the lower third of the thigh, the site of election, as affording the best chance of saving the patient's life.

THE OPEN OPERATION IN THE TREATMENT OF SIMPLE FRACTURES CONSIDERED IN ITS LOGICAL RELATION TO THE ASSERTION OF A NEGATIVE

It will be noted that the extrinsic splint regarded as a part of a truss is most effective when it can be secured in relation to a considerable extent of the upper and lower fragments. The joints in close proximity to the false points of motion, must of necessity be included within the operation of the truss. It is especially difficult to obtain a grip through the mass of soft tissues, upon the upper fragment in fractures near the hip-joint. In connection with particular difficulties in defining categories it is to be noted that radiography has placed within the hands of the surgeon a wonderful means of determining the exact condition of the broken bones. As the difficulties of accomplishing extrinsic control over adjustment and immobilization of the fragments become extreme, the motive for using intrinsic appliances gains in force.

In preantiseptic days, in the treatment of a compound fracture of the leg with much mobility at the site of fracture the author had discarded the immovable plaster-of-Paris apparel as too restrictive of surgical treatment of the wound. The supports of the limb sometimes did not have sufficient control

over the adjustment of the fragments. Occasionally in such cases the fragments were held by small iron wire staples. Into the superficial shell of each fragment was drilled a small hole and then the staple was lightly hammered into place. These staples had only a feeble hold upon the fragments and worked loose in three or four days.

To act more efficiently the author constructed a bridge or truss which could be easily taken apart or assembled. It was made of steel screws carefully plated and a connecting member of soft iron that could be easily bent as desired with tools always at hand. First, in each fragment was drilled a hole barely large enough to take the thread of the screw. The hole went through the superficial shell of bone down to the inner surface of the opposite side of the shaft. The screws were then driven home, their ends resting against the opposite inner surface of the shaft, and were thus firmly implanted. Next, the fragments were adjusted in position and the connecting member consisting of the strip of soft iron which was slotted near its ends was so bent that it could be slid into position in the open slots in the bodies of the screws when the fragments were adjusted. Then iron wedges were pushed into the slots of the connecting member filling the open spaces on each side of the bodies of the screws. Finally, the detachable caps or heads of the screws were screwed on, consolidating the bridge or truss into a rigid whole. This bridge or truss was more efficient than the common iron wire staples, yet it worked loose in a few days and was removed. The drilling did not seem to harm the

bones. The drill-holes speedily filled with granulations.

This contrivance, together with the rest of the complicated and delicate constructions described, was discarded to give place to the practice of antisepsis which placed the treatment of compound fractures and the adaptation of extrinsic apparel in a category closely approaching that of simple fractures.

It is well to impress upon the mind, that in the formation of categories in which given incident conditions embodied in treatment are the subject of negative assertion, a single successful affirmative instance in the given category is logically destructive of the universality of distribution of the negative assertion essential to the validity of argument. For example, it may be said that in the category of recent oblique simple fractures in the lower third of the shaft of the femur with much shortening, the open operation with intrinsic fastening of the bony fragments is necessary, which is tantamount to asserting the denial that in the given category other methods, perhaps embodied in extrinsic apparel, are productive of equally good union of the bones in correct position. This negative assertion derives its logical force from the universality of its distribution. A single successful instance of treatment by extrinsic support limits the universality of that distribution, destroys the validity of the argument and leads to the necessity for the creation and definition of new categories.

The photographs (see Plate XVIII) show different views of a specimen of an oblique fracture at

PLATE XVIII.

Oblique Fracture of the Lower Third of the Shaft of the Femur, perfectly United in correct Adjustment without Shortening or other Deformity. Old osteophyte at middle of the shaft.

the lower end of the shaft of the femur which has not only an interesting history, but strikingly illustrates the meaning of what has been said regarding an affirmative instance limiting the universality of distribution of the negative proposition.

The patient from whom the bone was taken was the first instance of fracture of the shaft of the femur which was ever treated by the author. Shortly before admission to the Hospital the patient suffered from a simple fracture of the shaft of the femur from direct violence with considerable shortening of the limb. There was little tendency to swelling of the injured soft parts. The writer applied an immovable plaster-of-Paris splint immediately. The patient was out of bed in a day or two, walking about on crutches. He made an uneventful recovery. Upon removal of the splint, only one having been applied, the fragments were found united without shortening or other deformity. In time the patient was discharged, cured, from the Hospital.

Several weeks later he was admitted into a medical ward of the same institution suffering from nephritis from which he died.

The bone, through the many years it has been kept, has suffered some disintegration at its spongy ends but without impairment of its value as a specimen of united fracture without deformity treated in the plaster-of-Paris splint. The osteophyte is, of course, extraneous to the subject under consideration. It will be observed that although the line of fracture was oblique in the extreme, the union was in all respects a perfect one.

The union of the fragments in perfect adjustment as regards deformity shown in this photograph of the fracture at the lower third of the femur was achieved before the discovery of radiography, when it was therefore impossible to show the perfection of results in life as by an exhibit of the bone itself.

So far as tests could be made by measurements and otherwise, perfect results like that shown in the author's instance were the common occurrence. This is even well shown through the applied splints in the photograph of the patient with fracture at the middle of both thighs.

The results were often so perfect that the writer himself has sometimes heard a celebrated authority, averse to the method for personal reasons, declare in examining some patients that he had no evidence that the thigh-bone had ever been broken.

The objection to the use of the immovable plaster-of-Paris splint in treating simple fractures of the shaft of the femur was not directed against the character of the results achieved, which in expert hands were conspicuously superior to those of other methods then in use, but was against the necessity of using that high degree of skill for its perfect construction only possible at the hands of trained operators.

The use of the splint was therefore not primarily a question of results but of skill. The important question arises, should skill be cultivated to that degree capable of attaining results of higher value, or, should inferior results be accepted, that are within the reach of a lower degree of skill and consequently more generally obtainable. To avoid an easy appli-

cation of the *reductio ad absurdum* to the argument for lowering the aim in accommodation to a lower degree of skill, but one answer is possible. Clearly, skill should be cultivated to the degree of obtaining results of higher value. Such cultivation of skill belongs to the function of educators. Since practice founded upon experience is a necessary qualification in such education, it follows that some degree of specialization will probably be necessary to furnish the needed instances for experience.

It will be noted that some of the open operations on fractures of long bones now somewhat in vogue are performed to correct the results of initial faulty treatment. For that purpose they are a valuable resource. Such instances lack force in an argument against the original procedures when properly performed and speak loudly for the cultivation of skill since proper measures of treatment carried out with adequate skill in the first instance might have produced satisfactory results, thus doing away altogether with the need of the corrective measures of the open operation.

The argument for the general performance of the open operation is not parallel to, or comparable in cogency with, that of the open operation for suturing simple fractures of the patella. In the latter class of injuries the infolded fringe of tissue practically always prevents contact of the bony surfaces in apposition, and the open operation is therefore necessary to lift away the interposed tissue to insure bony union. In fractures of the long bones generally, interposition of tissues sufficient to prevent union under

proper methods of treatment is a rarity. The author has never seen but one instance. In that injury, a compound fracture of the leg, the loose, detached transversely interposed fragment was easily removed. The burden of proof rests upon the operating surgeon to show that such an interposition of tissue or other adverse condition exists in the given instance to constitute a bar to union or union without deformity under the best prescribed conditions of treatment, consequently creating the necessity of the open operation. While deprecating the procedure as a routine measure the writer does not deny that exceptionally such states of fracture may occur and consequently that infrequently the open operation may be advisable as a primary procedure.

If there exist categories of conditions of the fracture of the shaft of the femur either in location or character of the fracture in which the non-operative treatment would fail in producing like happy results to the one shown in the writer's specimen, it is highly important that such categories embracing the exceptions should be accurately defined.

In view of the large number of successful instances in which union without shortening or other deformity has been achieved by skilled surgeons throughout different regions of the shaft of the femur under a wide range of conditions of fracture, and under different procedures of treatment, the great difficulty in creating and defining categories of exceptions in which the open operation is a necessity is evident.

It is always to be remembered that a single successful exception in any such created category by limit-

ing the universality of distribution of the negative proposition vitiates the logical force of the category in substantiating the assertion of the negative, that is, in asserting the denial of the sufficiency of some non-operative method to attain the proposed good result.

The burden of proof in justifying their action rests, of course, with those who would assert the negative. The force of such proof must be overwhelming to justify as a routine method of treatment the conversion of recent simple fractures into compound fractures, when results equally good or superior may be obtained without inflicting a serious superadded and unnecessary wounding of the patient and exposing him to the risk of infection, which, when it occurs in fractures of the shaft of the femur is a serious disaster. When suppuration has spread among the muscular planes of the thigh the author is of the opinion that amputation affords the most efficient drainage.

The patient with simple fracture of both thighs (see Plates X and XI) would have been in a pitiable plight had he been treated by the unnecessary open operation, wherein, according to one apostle of the method, "The incision which is always long" is "from eight to ten inches." It is further to be noted the intrinsic means "must be considered only of value merely to approximate the fragments and not at all sufficient to hold them. For this purpose the whole reliance must be placed upon the solid external plaster case, most accurately and carefully applied. If this does not succeed in absolutely immobilizing the fragments, the operation may fail."

In view of occasional fallacies it is to be noted that a bad result consequent upon an error in judgment, fault of skill, or from any cause, in the performance of this operation, as in the case of all operations, does not in itself constitute a basis for argument against the value of the result obtained in the successfully performed operation.

The author quotes in full from a recent Hospital Report omitting the confirming radiographs, the report of a successful instance of non-operative treatment of a simple subtrochanteric fracture of the femur, as an instance limiting the universal distribution of the negative proposition and therefore destructive to the validity of the argument in favor of the necessity of the open operation for the given group of patients.

"Two weeks previous to admission this patient, a lady forty-eight years of age, had sustained this injury while on vacation in the country. When brought to the city and admitted to hospital the . . . upper fragment was flexed and abducted and the lower fragment was drawn upward producing a shortening of one and a quarter inches.

"The patient was somewhat stout in habit and of highly nervous temperament. The difficulties to be overcome in securing satisfactory reposition of the fragments were appreciated. We were familiar with the fact that in this class of fractures position and traction are usually so inefficient in overcoming displacement that such a fracture is recognized as one in which exposure and plating are especially indicated. We hesitated therefore to rely on position

and traction in this case, notwithstanding that in no case of this kind previously under our care had we failed to get a satisfactory result either as regards function, deformity or length.

"But in this particular case, taking into account the length of time since the injury had been sustained and the peculiar physical and temperamental status of the patient, we earnestly advised that the fracture should be exposed and coaptation secured by plating. The patient herself, however, would not accept this proposition, but insisted that first a non-operative treatment should be tried. This was therefore instituted. A slight flexion was obtained by keeping the leg on a sliding Volkmann's apparatus, which also reduced to a minimum the friction resistance to the full effect of the extension traction. Counter-extension was provided not only by elevating the foot of the bed, but also by the use of a suitable perineal band secured to the head-post of the bedstead. A pelvic band held the pelvis to the side of the bed corresponding to the sound limb, so that by placing the traction pulley at the foot of the bedstead, close to the opposite post, a good angle of abduction was secured. The perineal counter-extension band, the pelvic lateral band, the sliding leg support and abducting extension adhesive strips, kept taut by the weight at their end, all formed a very excellent confining harness that still was not intolerable, and, as the event proved, was well borne by an unusually restless and intolerant individual. This traction weight was rapidly increased up to twenty-five pounds. This was well borne and within a few days the length of the

injured limb was brought to the same measurement as that of the sound one. Consolidation proceeded in normal rapidity and at the end of ten weeks the patient walked out of the hospital with the aid of crutches. . . .

"Examination made four months later confirmed the facts that the length of the two limbs was equal and that no deformity was exhibited by the injured thigh.

"We are reporting this case somewhat fully, not with a view of in any way reflecting upon the value or propriety of subjecting such injuries frequently to exposure by incision and to plating, but as an example of the possibility of securing excellent results by more conservative methods whenever for good reasons prudence dictates the avoidance of special hazards which must always attend the more radical and perhaps more efficient operative methods."

The foregoing instance, which in its logical bearing will repay the most thoughtful study, establishes by strongest proof that for the specified patient the open operation by incision and plating was not an operation of necessity. This conclusion is placed beyond doubt by the statement of the surgeon himself.

The eminently able surgeons in charge of the patient, on account of the unusual length of time that had elapsed between the time of the occurrence of the injury and the date of the beginning of treatment, together with peculiarities of temperament of the patient, were inclined to doubt that the specific instance could be included in that category of which they affirmed "in no case of this kind previously under our

care had we failed to get a satisfactory result either as regards function, deformity or length." The event proved, however, that the patient was no exception, belonging to a different category calling for other conditions of treatment.

Admitting that the open operation by incision and plating could have secured equally good union of the fragments in correctly adjusted position as that which was actually achieved by the non-operative treatment, the impersonal proof of the comparative value of the differing methods of treatment open to choice remains to be established.

It is not enough to verify the facts comprehended in given results, the comparative value of these results in their elements of dissimilarity must be proven. This being accomplished, the conduct of the surgeon in adopting his choice of methods is governed by ethics, and is under the control of the social organism.

TREATMENT OF SEPTIC WOUND COMPLICATIONS; COMPOUND FRACTURES AND PRIMARY AMPUTATIONS

The practice of acute septic surgery is a delicate branch of surgical art requiring trained judgment and educated hands to promptly deal with the quick changes in the tissues.

Septic patients stand the loss of blood badly; a very small additional loss of blood being enough to turn the scales fatally against them.

In the treatment of septic compound fractures and amputations it is a great error, the author conceives, to bandage absorbent dressings about the wound. The disturbance of the inflamed septic tissues in the act of changing dressings alone inflicts great injury. Such tissues have very feeble resistance and do not tolerate handling, not to speak of the dissemination of the infective material. Such wounds should be left undisturbed, at complete functional and physical rest.

The apparatus devised by the author for the treatment of amputations of the thigh, the arm and forearm, together with compound fractures in the upper extremity, was very simple in its construction and satisfactory in its action, and might be especially serviceable in military surgery. It is well shown in the instance of the treatment of the amputation of the

PLATE XII.

Recent Primary Amputation at the Thigh, Treated by Suspension on Frame. Duplicate clean frame shown at the right. No dressings upon the wound.

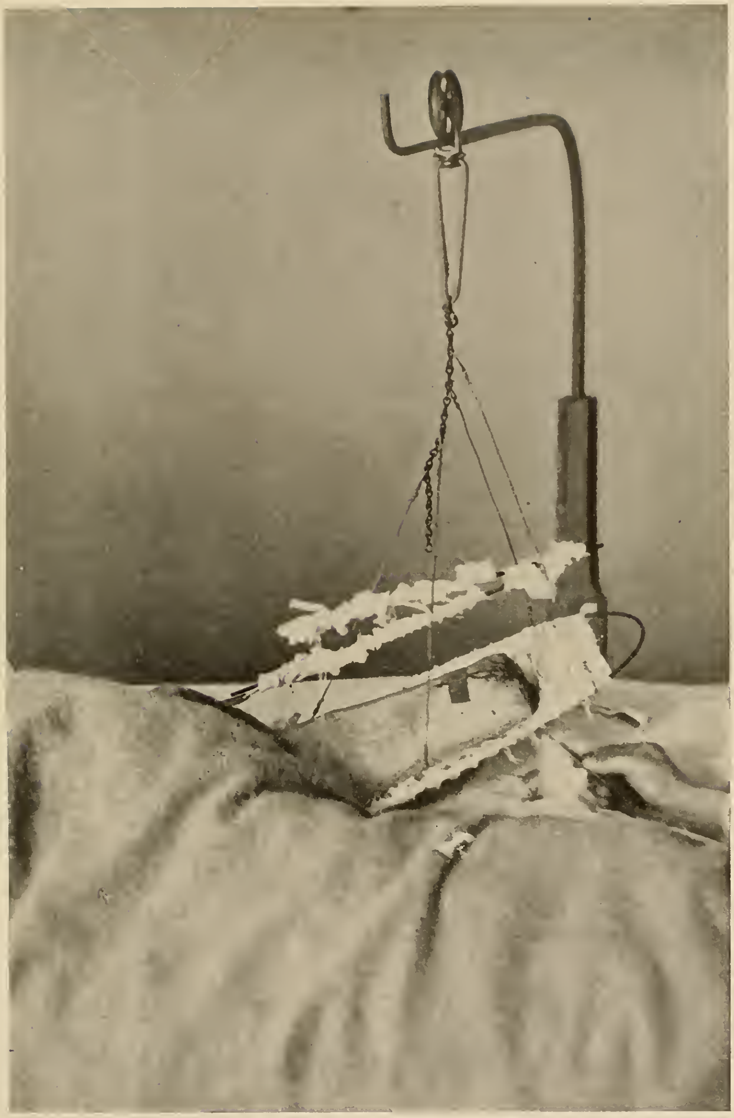

PLATE XIII.

Recent Primary Amputation at the Thigh. The clean support has been substituted for soiled support. Strips of soiled support are being removed. Wire of soiled frame has been lifted away in removal. No dressings upon the wound.

thigh. It consists of a steel wire about one-fourth of an inch in diameter, bent to conform to the general outline of the limb. The wire is given a spring outward to keep the covering of the frame upon the stretch. The branches of wire are tied the proper distances apart. The skeleton wire frame is covered by bandaging with one inch wide bandage.

To cover the frame with bandage, an assistant holds the frame at the open end, keeping upon the stretch the piece of bandage holding the branches of wire the proper distance apart. The surgeon, beginning at the closed end of the frame, ties the end of the bandage to his left-hand wire. He carries the bandage to the upper surface of the right hand wire, around which he makes one and a half turns. In making the last half turn the bandage is made to encroach upon one-half of the width of the turn already made, thus tying the bandage to the wire. From the under surface of the right hand wire the bandage passes to the under surface of the opposite or left hand wire, around which one and a half turns are made, the last half turn infringing upon or overlapping one-half the width of the turn of the bandage already made, fastening the bandage to the wire. From the upper surface of the left hand wire the bandage is continued across the frame to the upper surface of the right hand wire, being applied about the wire slightly in advance of the previous turn already made.

Some little degree of practice is required to make the bandage covering of the frame of even tension, and to tie the bandage firmly round each branch of wire. When properly constructed, the covering

bandage is so firmly secured to each wire that neighboring slips may be cut, and the uncut adjoining slips will still hold fast to the wire and support the tissues, as shown in the illustrations. The covered frame is tied at its ends to a bandage passed around the patient's body. The frame sustaining the limb is then suspended from the apparatus already described by lengths of wire picture-cord having hooks at each end, all of which can be easily made by the surgeon, the limb resting upon the support *without any dressing of the wound whatever.* To prevent the skin sticking to the frame the latter is smeared at the proper place with some kind of simple ointment. An excess of pus from the wound drains away between the narrow strips of bandage covering the frame; this drainage may be facilitated by snipping holes in the support without impairing its integrity. To change the treated wound to a clean frame, a duplicate frame covered with bandage is slid beneath the soiled one upon which the limb rests. The hooks are changed from the upper to the lower frame; the covering of bandage is cut all around near the wire of the soiled frame beginning at the open end of the frame, thus freeing the wire; the cut slips of bandage of the upper frame are then drawn down between corresponding ones forming the covering of the fresh support, pulled away and discarded. In the very amputation of the thigh shown in the illustration a fresh new frame supporting the thigh was substituted for the soiled one without awakening the patient from sleep.

In the case of the leg where there is much change in contour the support cannot be made in one piece

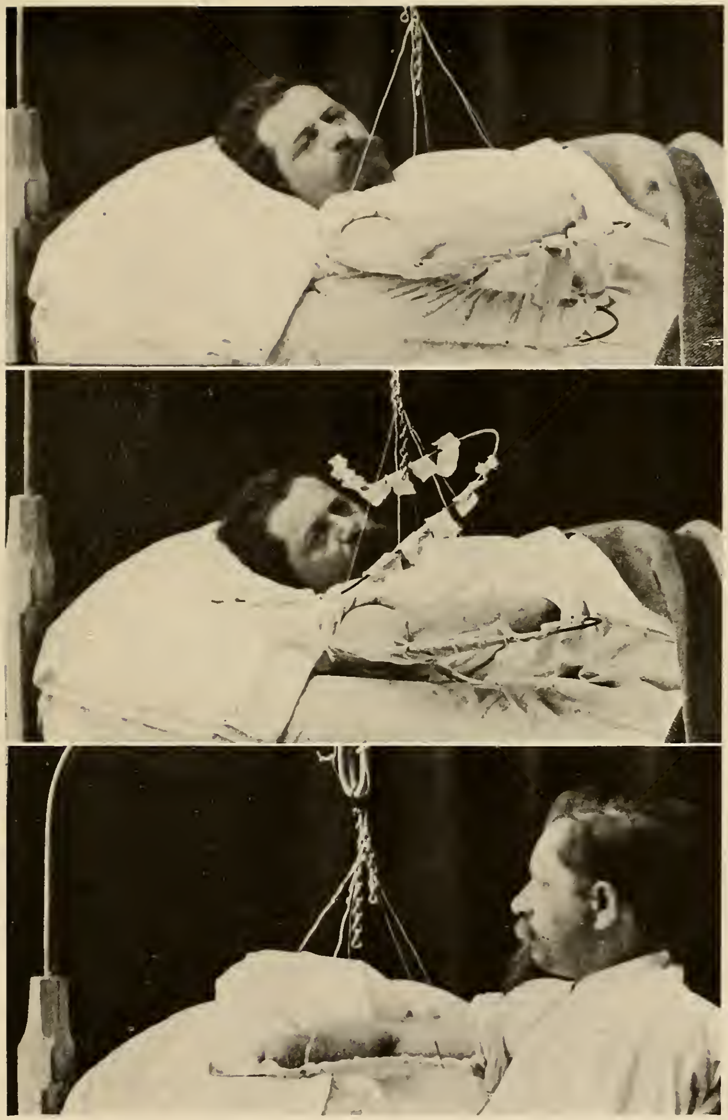

PLATE XIV.

Recent Primary Amputation of the Forearm, Treated by Suspension, without Dressings upon the Wound.

Upper Figure.—Clean frame beneath soiled frame.
Middle Figure.—Wire of soiled frame removed.
Lower Figure.—Limb resting upon clean frame.

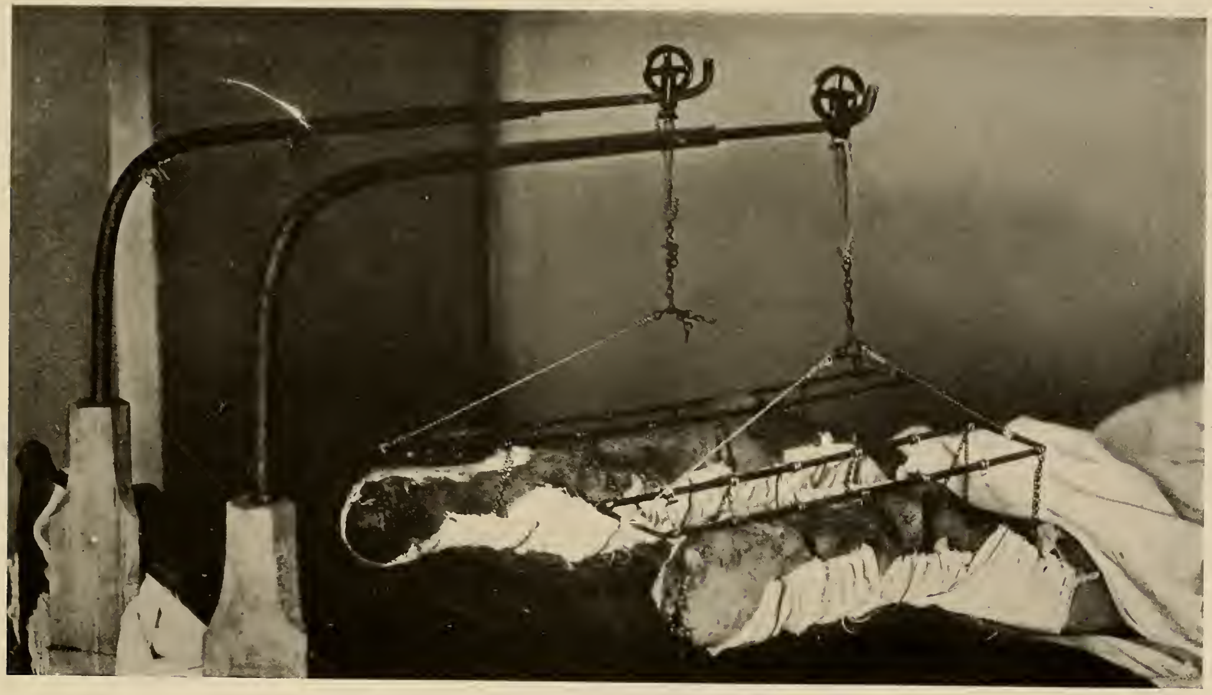

PLATE XV.

Amputation at Ankle-joint (Syme) and Middle of the Leg (Stephen Smith), Treated by Suspension and Resting upon Sectional Supports. No dressings upon the wounds.

PLATE XVI.

Upper Figure.—Compound Fracture of the Leg, Treated in a Fracture-box.

Lower Figure.—Same Compound Fracture of the Leg, Treated in Suspension Apparatus with Sectional Supports.

but must be divided into sections. Plate XV shows a double amputation, a Syme and a Stephen Smith side-flap amputation treated upon sectional supports.

Plate XVI, upper figure, shows a compound fracture of the leg which is under treatment in a fracture-box. Several incisions have been made to deal with spreading suppuration. Obviously, had the limb been treated in a plaster-of-Paris splint the splint would have been restrictive of those surgical measures demanded by the wound complications. In dressing or changing into a clean fracture-box the limb was necessarily disturbed in violation of one of the cardinal principles of treatment of septic wounds, which demands that the limb be kept at physical rest, and, if possible, not even handled. In the fracture-box the lower fragment remains stationary, while the slightest motion of the patient disturbs the upper fragment.

Plate XVI, lower figure, shows the same limb in apparatus which permits the freest surgical functioning while the fragments, as shown by the outline of the limb, are preserved in even better position than in the fracture-box. The sectional supports are so contrived that any one or two of them may be temporarily removed without impairing the efficiency of the general support of the limb. *No dressings are used* except a piece of lint spread with some simple ointment to cover the granulating surfaces. The sectional supports are of bandage carried by a single iron wire bent into such form that when the section supports the limb there is no contact of the wire with the tissues. The supports are adjustable by means of the links of the chain catching into the hooks fastened to

the steel frame. Provision is made for balancing the limb and for its elevation or depression.

The construction shown in Plate XVII was a development of that shown in Plate XVI, lower figure. It was designed to exert a greater control over the fragments. A base line was provided by the use of a square brass bar which while strong enough to hold the suspended limb yet could be bent by the surgeon into desired form. To make the bar adjustable in length for use upon different limbs it was cut in two, and the two portions firmly held together by two clamps (see Plate XVII, lower figure). The bar was drilled transversely throughout its length, making holes about an inch apart. At first these holes were made only large enough to receive snugly the small hard brass wires carrying the sectional supports. It was so constructed that when the sectional supports were in position the friction alone developed by the weight of the limb would hold immovable the wires passed through the bar.

It was found desirable, however, on account of wear to be able to key the wires in any given position. This was done by drilling another hole of the same size alongside and infringing upon the holes already made through the bar. Consequently a small piece of brass wire like that used in the sectional supports, bent at a right angle and slightly tapered at one end, could be pushed into the second hole keying the wire fast that had been passed through the hole alongside. By this means the carrying wire of the sectional support could be held in position with great accuracy of adjustment.

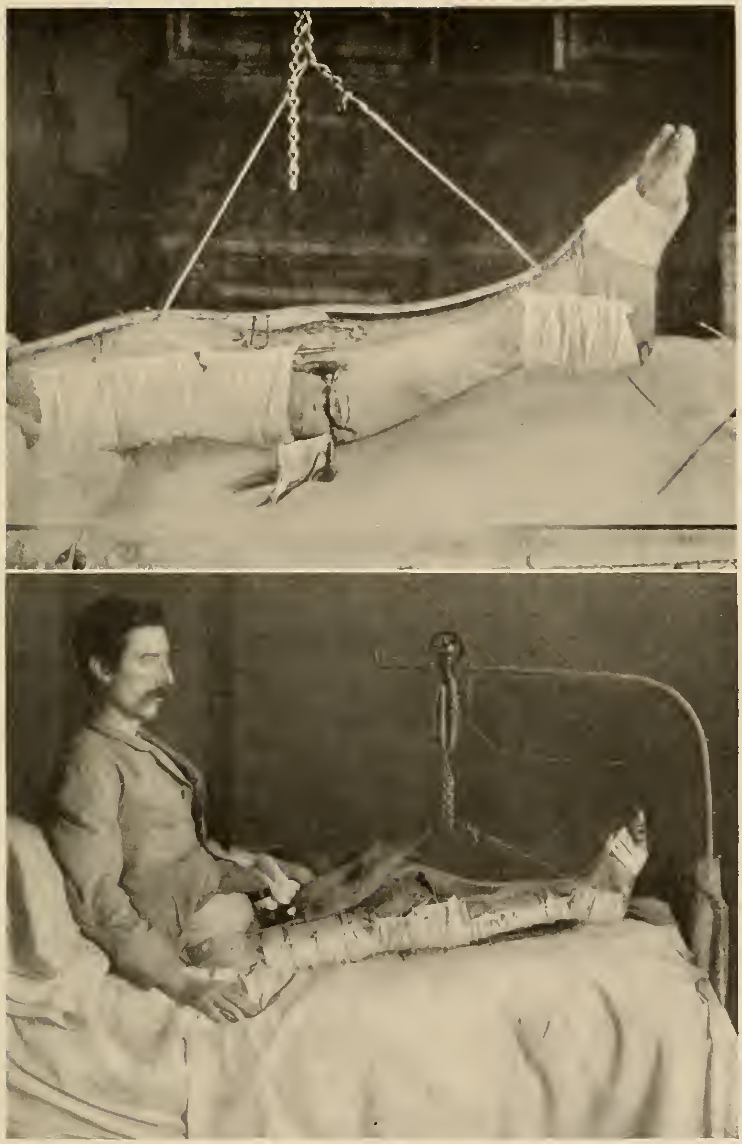

PLATE XVII.

Upper Figure.—Compound Fracture of the Leg. Treated by Suspension and with Sectional Supports. Two supports and part of a third have been removed and an abscess incised.

Lower Figure.—Excision of the Knee-joint. Treated by Suspension and with Sectional Supports. No wiring or nailing of the bones.

Two crossbars mounted upon the carrying wire held the bandage constituting the sectional support. A narrow bandage was easily fastened to the crossbars in the same manner that the bandage covered the frames used to support the amputation of the thigh (see Plate XVII, upper figure). Thus constructed even a portion of the bandage of the sectional support could be cut away and the remaining portion of the bandage would hold fast (see Plate XVII, upper figure). The bar constituting the base line was fastened at one end to a band of simple webbing which made one turn of a spica about the pelvis. The other end of the bar was bandaged to the foot in the manner shown, holding it so it would not shift from position. Thus conditioned the injured limb while in absolute rest was in an attitude for extended surgical functioning. It was open to inspection, palpation and surgical treatment. The suspension of the limb was adjustable and the patient enjoyed a considerable range of motion without disturbing the immobility of the adjusted fragments.

The advent of the antiseptic treatment of wounds led the author to discard the use of the special apparatus described. Through effective antisepsis compound fractures were brought into a category closely approaching simple fractures, and treated accordingly.

While the complex of conditions comprehended under the term antiseptic measures may be easily formulated, it is to be borne in mind that the practical application of those measures, and full realization in practice of antisepsis depend upon the surgeon him-

self, a factor of the first importance, although of great and incalculable variability.

It is almost amusing to note in surgical literature how, sometimes, a surgeon, in excusing unfortunate mishaps, has sought to limit the range of antiseptic efficiency by naïvely "begging the question" in reference to his own employment of antiseptic measures.

It will be observed (Plates XII and XIV) that the amputations of the thigh and forearm are placed in a state of physical rest. The tissues are also so conditioned as to be capable of an extended range of surgical functioning and are not necessarily subjected to any special therapeutic influence.

It is emphasized, in repetition, that the discarded apparatus has been described not in any special advocacy of its use, but in exposition of the extension of the principles which it embodied.

The author not using dressings upon wounds became unaccustomed to expressions of pain on the part of patients in the usual dressing of their compound fractures and amputations and as a consequence well recalls the following incident:

On a visit to a large surgical hospital the author was invited by the distinguished and veteran surgeon who had operated upon the patient to witness the dressing of a recent primary amputation of the thigh in which he took particular pride.

At the surgeon's approach the patient's face became clouded with anxiety. The wound dressing consisted in binding a quantity of loosely shaken, fluffy oakum about the stump. After the removal of the old dressing, which was sodden with decomposed

pus, an assistant industriously squeezed the stump till the last drop of pus was expelled from the sinuses communicating with the wound. The wound and connecting sinuses were then thoroughly syringed with a watery solution of carbolic acid, and finally the new oakum dressing was bandaged to the stump. In doing this, an assistant stood upon the bed astride the patient, whom he lifted while the bandage was being carried around the pelvis. At last, the patient sank back exhausted and exclaimed: "For God's sake, doctor, stop and let the wound have a chance to heal!"

The observed procedures were justified by prevalent practice, and were carried out under the direction of the operating surgeon who did not seem to realize that his patient, in the dressing of his wound, lost as much energy in a higher form, as would have followed a considerable blood-letting. According to the author's usual procedure all that wasted energy accompanied by manifestations of pain would have been saved to the patient.

SCOPE OR DEGREE OF EXTENSION CONSIDERED IN REFERENCE TO PRINCIPLES EMBODIED IN SURGICAL PROCEDURES

In the comparison of methods of treatment the consideration of scope or the degree of extension of embodied principles is of great importance.

For example, in the case of the tin strips it has been stated that the fixation of the bony fragments in a given relation is achieved in a minimum time. Increase of speed in immobilizing the fragments is in itself an increase of scope.

Furthermore, the strips may be fastened in position, thereby insuring the quick fixation of the bone either by a dry, wet, plaster-of-Paris, starch, water-glass or other kind of bandage that may be chosen for the construction of the enveloping apparel. This is an increased range of choice of material in the construction of the permanent splint.

Increased scope is illustrated in the use of the writer's crochet-drill in the suturing of simple fractures of the patella by the open operation, the essential element of the operation being the holding of the fragments in the desired relation by suturing.

In usual drilling when the drill is withdrawn, tissues are apt to slip over and obscure the drill hole, making the passing of the suture very difficult.

Again, the fragments must often be tilted or the joint flexed to enable the operator to secure the end of the suture as it merges upon the under surface of the bone at a definite point. In other words, the efficiency of the ordinary drill is restricted to a very limited distribution of conditions.

By the author's method there is no need of such tilting of the fragments. They can be drilled and the suture can be passed with facility in any position of the joint, preferably, of course, in the position of election, that is, when the limb is extended, and without interference with the cavity of the joint. Again, according to the usual method the drill hole is sometimes made unnecessarily large and so cleared of tissues as to expose the bone to the risk of a slight necrosis. According to the author's method the drill hole need be no larger than to receive a suture and the nutrition of the bone need not be endangered.

The crochet drill designed by the writer for use in suturing simple fractures of the patella is a drill with a slightly enlarged flat

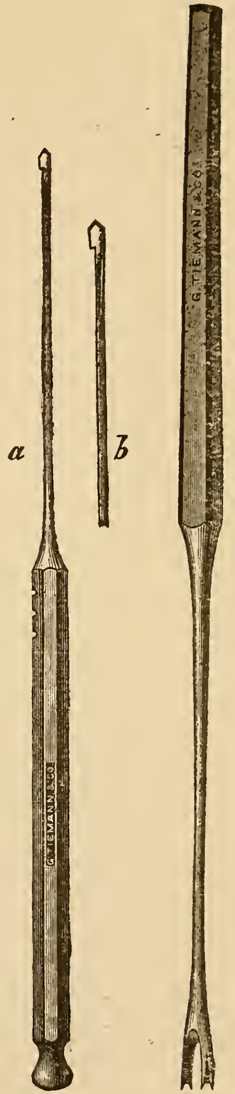

Fig. 5. — Hand Crochet-drill and Fork. Two-thirds of actual size. End of drill, b, actual size.

head. In the head of the drill is cut a small notch only large enough to receive a silk thread (see Fig. 5). The shank of the hand drill is of the same size throughout, about one-sixteenth of an inch in diameter, is spring tempered so that the pressure of the hand constantly keeps the cutting edge of the head of the drill at its work. The enlarged size of the head of the drill converts the drill into a sort of probe and the varying resistance of the tissues through which it passes can therefore be differentiated. The head

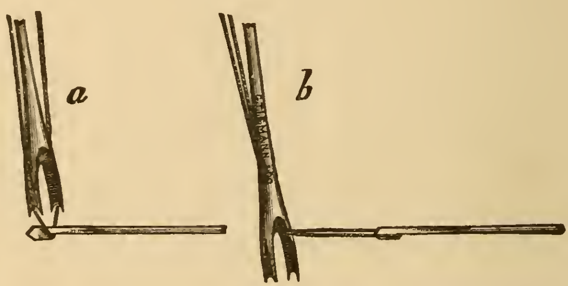

Fig. 6.—Use of Fork in placing Loop of Silk in Notch of the Crochet-drill.

of the drill having passed through a fragment, a loop of silk is cast over it and caught in the notch either by means of the tip of the finger or by the specially designed fork shown in Fig. 6. The loop of silk is then drawn through the drill hole by the withdrawal of the drill, thus holding the path made by the drilling. By means of the loop of silk any sort of suture can be drawn into position. (See Fig. 2.)

The hand-power mechanism shown in Plate XIX was designed to shorten the time of drilling, and is

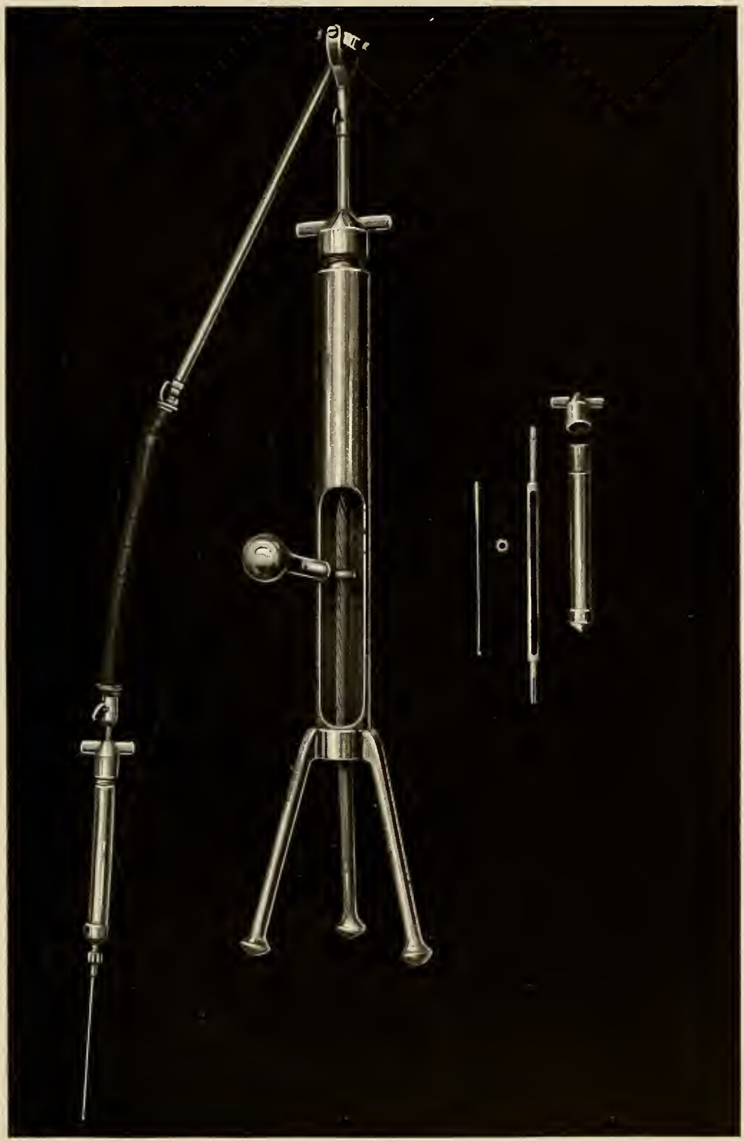

PLATE XIX.

Hand-power Mechanism of Crochet Drill. At the right, the drill-handle taken apart.

especially useful when the bony fragments are hard. The contrivance is an adaptation of the Archimedean spiral which in action makes the same number of positive and reverse turns, thus preventing the head of the drill from picking up shreds of tissue and fouling. The mechanism is very simple in construction and action. It is sectionalized and can be readily assembled without accessory tools. It is, of course, capable of being perfectly sterilized. In action the assistant working the power stands on the opposite side of the bed away from the operator and the field of operation. He holds the body of the mechanism by his left hand, firmly pressing the three legs against his breast while he actuates the drill by working the handle back and forth with his right hand. The drill being governed by the flexible wrist motion of the operator there is no need of making the shank of the drill of spring temper.

Upon trial on several occasions the mechanism fulfilled with perfect satisfaction the purposes for which it was designed. It shortened the time of drilling the patella fragments from several minutes to a minute and a fraction.

To show the range in choice of suture materials with the author's method, he once drilled two pieces of soft pure rubber, each an inch thick and accurately united them with a heavy silver wire and the finest human hair.

The author's method of drilling, therefore, expressed a gain in scope, preserving its maximum efficiency under widely varying distributions of conditions.

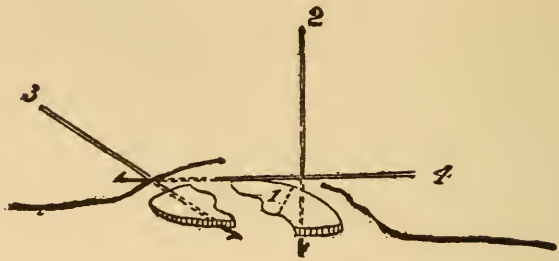

Fig. 7.—Drilling of Irregular Fracture of the Patella while the Knee-joint is Extended.

Explanation of Figure 7.

In an actual case "The transverse fracture had taken a very oblique direction through the thickness of the bone so that the broken bony surface of the upper fragment widely overhung its cartilaginous margin. In drilling the upper fragment, 1, deceived by the obliquity of the fracture, the point of the drill was made to emerge through the cancellous tissue some distance above the bony cartilaginous junction. As the lower fragment could not be readily exposed, the drill was passed directly through the skin and soft parts to the bone, 3, its point emerging through the under surface of the cartilage. It was clear that when the fragments would be wired together the upper fragment would be on a lower plane than the lower one and that the apposition would be quite imperfect. The misdirection of the hole through the upper fragment was corrected by drilling again, 2, directing the drill even a little upward to insure exit of the point through the under surface of the cartilage. By means of a properly constructed instrument (the Fork, see Fig. 6) the silk loop was cast over the notch in the end of the drill, which could be only reached by the tip of the finger. One end of the wire was drawn through the upper fragment and the other through the lower fragment and the skin. The drill was again introduced alongside of the wire emerging from the skin, 4, and passed superficially to the upper surface of the fragment. By means of a loop of silk drawn along the track of the drill, the wire was made to re-enter its opening of emergence through the skin and was pulled into place." See original communication by the author in the *N. Y. Medical Record* of June 7, 1890.

The sharp pointed sickle-curved bistoury shown in Fig. 8, was formerly known as an abscess knife, its special use being for the opening of abscesses. It will be observed from its curved shape, it cannot be well aimed. The sharp point penetrating the cavity of the abscess meets with increased resistance as it is pushed onward through the tissues.

Fig. 8.—Ordinary Curved Bistoury, used for Opening Abscesses.

The abscess knife designed by the author, shown in Fig. 9, being straight, can be well aimed to reach a small collection of pus deeply situated. As it is pressed onward the entrance of the end into the cavity of the abscess can be readily noted because the grasp upon the blade by the tissues becomes less as

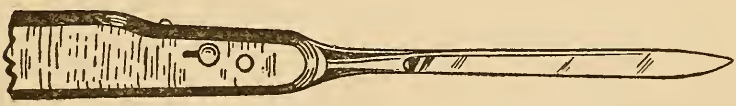

Fig. 9.—Author's Design of Knife for Opening Abscesses.

it advances, since the cross section of the blade lessens in approaching the heel. The knife acts somewhat like a probe. Turned slightly upon its long axis, the contents of the cavity ooze along the side of the blade and disclose their nature, the blade acting as an exploring needle. Turned quickly back into its original position, thus keeping the cavity full

of contents, the end of the blade is pushed across the cavity till it strikes the inner surface of the opposite wall, and then while the point is held fixed in position, the handle is swept upward, thereby cutting open the cavity the desired extent. It has increased range as an exploring needle and as a probe. It expresses an increase in scope.

The handle of the scalpel may be considered from the standpoint of scope.

When the author was a student, it was customary for the surgeon to carry his own instruments, as needed, from place to place. Even the great Bellevue Hospital at that time had such a poor supply of instruments that it was usual for operators to provide their own instruments at the great surgical clinics. The knife-handles were made very thin in order that a number of knives might conveniently be packed in a small space in the surgeon's case. The handles were given their particular form to suit the instrument-maker and not from surgical reasons. Many years ago the writer whittled the model of his knife-handle into desirable shape. Such a handle was thick and very nearly octagonal in shape. Since those early days hospital equipment has undergone a great change. The thin flat handle in development has given place to one of thickness and octagonal in shape. The thin handle restricts manipulation largely to wrist motions. The latter design, while not excluding wrist motions, allows finger motions permitting the rolling of the handle upon its long axis between the fingers—in other words affording a gain in scope.

The patient with brain injury who was the subject of erysipelatous infection is shown in Plate XX, Fig. A.

The six weeks' old brain sinus with resisting walls was easily probed with an ordinary probe. With the recently inflicted wound, however, conditions were quite different, and a surgeon who thought of using an ordinary probe according to old procedure might well have been pardoned for refraining to attempt thus to locate the bullet.

In further detailed exposition of the construction of his probe and the principles of probing wounds the author makes the following extract from his contribution to the *New York Medical Journal* of March 28, 1885, describing the successful extraction of a pistol-ball from the brain by a counter-opening in the skull.

"In probing a wound it is essential that the end of the exploring instrument shall be of such a size as not easily itself to wound the tissues and make a false passage. The end should therefore be large. Not only does a large extremity to the probe save the tissues from injury and diminish the chance of making a false passage without the exercise of an undue amount of force, but the large end, even when it is deep beneath the surface of the body, is easily discoverable by palpation or dissection.

"In probing a wound to learn its course, depth and other features, we should be able to follow or infer with exactness from the exposed portion of the instrument, the varying positions of its buried end. It is further essential therefore that the end should hold

Fig. 10.
Author's Design for a Probe.
Actual size, except the length, which is twelve inches.

a fixed relation to the shaft, or, in other words, that the probe must have sufficient rigidity to retain a given shape. This rigidity is requisite to the practice of another procedure to determine the location of the exploring extremity, namely conjoined manipulation through the medium of the probe. The shaft of the probe should not only be rigid but should also have a considerable bulk, that a large surface may be in contact with the fingers and subject to the informing touch. Finally, the probe fulfilling these requirements should be as light as possible in order that the delicacy of touch should not be lessened in the exertion to move a heavy mass and that vibrations that would otherwise be lost in the probe itself may be communicated to the hand.

"The probe combining these properties has the shape (shown in Fig. 10) and is made of tempered aluminum. The large end will generally pass along the sinuses connected with a wound and from its size and shape it is often possible to tell the nature of the structures with which it comes in contact. It is only exceptionally that the smaller end need

be used. In probing, to curve the instrument is to complicate it and increase the chances of error in interpreting the position of the exploring extremity.

"When the probe is curved near the exploring end, the other end of the shaft should be bent in the same plane in the opposite direction.

"In case the sinus is tortuous, rather than complicate the exploring instrument I am in the habit of simplifying the wound. Thus, in following such a sinus

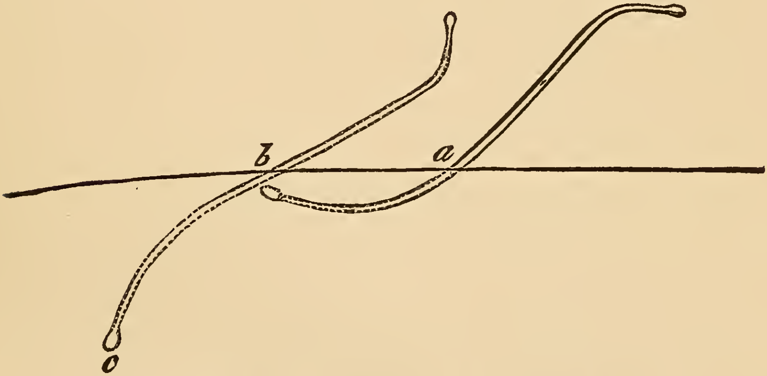

Fig. 11.—Method of Probing a Tortuous Sinus.

the end of the instrument after it has passed along one curve (Fig. 11) should, if practicable, be brought toward the surface and exposed by careful dissection. The first curve having been eliminated the rebent probe can be introduced through the new opening at *b,* the commencement of the second curve *bc,* and the latter explored."

In the illustrative instance described, the writer by his probe followed the path of a pistol-ball antero-

posteriorly through the whole length of the hemisphere of the brain, made a counter-opening at the indicated point on the opposite side of the head, inserted the probe in the new opening, followed the ball on its deflected course and extracted it, saving the patient, who lived for several years. (See *New York Medical Journal,* March 28, 1885.)

It is proper to add that the correctness of the principles involved and the capabilities of the probe as an instrument of precision were further confirmed by two other instances of brain injury, the only other cases that came under the author's care, and until now unpublished.

It is to be noted that the missiles in all instances were located by means of the probe alone, no assistance being derived from radiographs. A single error in passing the probe would have made the operation a failure.

In one patient the pistol-ball passed transversely through the brain and rebounded from the inner surface of the opposite wall of the skull for over an inch toward the centre of the brain. The large end of the probe was introduced through the opening of entrance. The skull was opened by trephining at the indicated point on the opposite side of the head. The probe being introduced through the new opening, the rebounded ball was traced to its place of lodgment, about one-third way toward the centre of the brain, and felt on the side of the wall of its initial path through the brain. The head was so placed that the principal path of the ball was perpendicular to the horizon. With the large end of the probe introduced

PLATE XX.

A. Upper Figure.—Pistol-shot Wound of the Brain, Six Weeks since Injury. The brain-wound had become a discharging sinus with walls of some resistance. The ball, lodged near the centre of the brain, was encysted. The sinus was followed by an ordinary probe which could not have been done in the fresh wound.

Lower Figure.—Shows the course of the probe to the contact with the ball.

B. Upper Figure.—Straight Course Antero-posteriorly of a Ball to the point of Contact on Inner Surface of the Opposite Side of the Skull. Very troublesome hemorrhage of a branch of the artery of the corpus callosum, shown in E, lower figure, was stopped. The ball was then tracked with a large probe to its point of contact with the opposite side of the skull. Judging from the exposed portion of the straight probe the concealed end of the probe was opened upon by a trephine at the indicated point upon the opposite side of the head. The probe was entered at the new opening and the deflected path of the ball was followed till the ball was reached and removed.

Lower Figure.—Shows the course of the path of the ball through the hemisphere.

C. Upper Figure.—Opening of Entrance of a Pistol-ball Behind the Right Ear.

Lower Figure.—Shows the Course of the Ball, Inward, Upward and Forward. Path of the ball explored by the large probe and place of lodgment of the ball established by contact with the probe. The author introduced his left index finger its full depth, felt the ball and with uterine tenaculum hooked the ball against tip of the finger and removed it.

D. Upper Figure.—Point of Entrance of Pistol-ball.

Lower Figure.—Dotted Line Indicates Course of Ball Transversely Across the Brain to Place of Contact with the Inner Wall of the Opposite Side of the Skull. Skull opened at indicated point by small trephine hole, probe introduced at new opening and the rebounded ball traced to its place of lodgment half way toward the centre of the brain.

E. Upper Figure.—Median Section of the Head showing Falx Cerebri in Position and Point Probably Pierced by the Ball in its Course Across the Head in Figure D.

Lower Figure.—The Inner Face of the Hemisphere After the Falx was Removed. Branches of the artery of the corpus callosum may be seen.

A B C D E

PLATE XX.

For description of this Plate see opposite page.

into the opening of entrance the ball was gently urged downward by the probe till it could be felt against the tip of the finger watching at the counter opening, and was then extracted (see Plate XX, Fig. D).

The head was replaced in normal position and the probe reintroduced transversely into the brain. When the large end was half way through the brain its progress was checked by a soft but distinctly felt resistance. Presently the brain was felt to move slightly and the probe was then passed easily onward through the head. To the smaller end of the probe were attached five or six strands of small-sized catgut, which were drawn through the brain to act as a drain.

Upon careful after-study it was established that the ball had passed through the falx cerebri (see Plate XX, upper figure, E). Without doubt in passing the probe transversely through the head the large end was halted against the edge of the opening through the falx, but upon the slight movement of the brain that opening was centred. The patient recovered and lived for more than five years.

In the third patient the pistol-ball entered behind the upper portion of the right ear, pushing fragments of bone before it. The patient displayed no nervous symptoms to guide, and there was much discussion as to the course of the ball. The probe revealed that it had passed inward, forward and upward. It was so much flattened that it could not be grasped with the bullet-forceps. The writer then passed his left index finger its full length into the brain and felt the ball at the tip end of the finger.

By sliding a delicate uterine tenaculum along the finger he hooked the ball against the tip of the finger and extracted it. Hemiplegia of the opposite side set in immediately, but wholly cleared up in twenty-four hours. The patient recovered and lived more than two years (see Plate XX, Figure C).

No test for probing a wound in soft tissue could have been severer than those imposed in these three patients. It showed the extreme range of probing through paths of wounds with delicate walls.

The educated touch, the "*tactus eruditus,*" is an extension of scope in manipulation. No illustrative instances are needed to emphasize its great importance.

In all fields, scope as a measure of value is acknowledged. The smaller range in scope is always at the mercy of the larger range. In final analysis all such increases in scope are resolvable into increases in responses. To pass from lesser to greater scope, is progress; to pass from greater to lesser scope, is regress.

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